Ecological Effects of the WICKERSHAM DOME FIRE Near Fairbanks, Alaska

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METRIC AND ENGLISH EQUIVALENTS

degrees Celsius = 5/9 (degrees Fahrenheit minus 32)
1 hectare = 2.47 acres
1 kilogram = 0.45 pound
1 kilogram per hectare = 0.89 pound per acre
1 kilometer = 0.62 mile
1 liter = 0.26 gallon
1 meter = 3.28 feet

General Technical Report PNW-90
1979

ECOLOGICAL EFFECTS OF THE WICKERSHAM DOME FIRE NEAR FAIRBANKS, ALASKA

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ABSTRACT

The Wickersham Dome fire occurred in late June 1971 and burned over 6 300 hectares of predominantly black spruce forest land. Shortly after the fire was controlled, studies of the effects of the fire on various components of the biotic community were undertaken. Results reported here are mainly for the first 3 years after the fire.

KEYWORDS: Fire effects, fire (-hydrology, soil properties (chemical), succession, fire (-regeneration, black spruce, *Picea mariana*, quaking aspen (*Populus tremuloides*), Alaska (Wickersham Dome).

HIGHLIGHTS

Examination of soil after the fire disclosed that moist, lower ayers of the forest floor had minimized the impact of the fire n the soil. Burning reduced the thickness of the forest floor ayer an average of 10.3 centimeters in heavily burned areas and .7 centimeters in lightly burned areas in a study location where he thickness averaged 28.7 centimeters in unburned areas. Burnng did not have a measurable effect on the chemical properties f the underlying mineral soil. The reduction of forest floor hickness and the blackened surface resulted in higher soil temeratures. These higher temperatures caused a substantial etreat of the permafrost layer in burned areas. Depth to permarost averaged 84 centimeters for burned areas and 47 centimeters or the unburned control 3 years after the fire.

Development of vegetation after the fire was closely tied to everity of the fire. On one lightly burned black spruce site, ive ground vegetation cover still totaled 40 percent after the ire and included considerable amounts of mosses and *Cladonia* ichens. Vegetative cover at this location had increased to 0 percent 3 years after the fire. In contrast, recovery of egetation in heavily burned black spruce stands was much slower. o mosses or lichens survived the fire, and most early cover was ontributed by such herbaceous species as horsetail (*Equisetum ylvaticum*) and fireweed (*Epilobium angustifolium*). Few invading pecies appeared after the fire; most postfire cover was contribted by residual species which reproduced vegetatively. Biomass roduction was extremely variable over the burned area and, at he end of the 3d year, ranged from 33 grams per square meter in heavily burned black spruce stand to 804 grams per square meter mostly aspen sprouts) in a heavily burned aspen stand. Studies f leaves and needles in litterbags indicated that rates of deomposition were the same in burned and unburned stands. The st year after the fire, black spruce seed fall in the burned lots was almost four times as great as that in the unburned ontrol. The germination capacity of black spruce seed was low n heavily burned areas and tended to decrease with time. On urned plots, only 1 percent of germinable seeds actually develped into established seedlings.

Studies of animals after the fire focused on arthropods, icrotine rodents, and snowshoe hares (*Lepus americanus*). Numbers f spiders, Collembola, mites, Coleoptera, and other arthropods ere higher in the burned area than in the unburned control. umbers of northern red-backed voles (*Clethrionomys rutilus*) were ubstantially reduced after the fire, and the voles did not verwinter in the burned area until 3 years after the fire. The undra vole (*Microtus oeconomus*), although rare in unburned black pruce stands, also established a resident population in the urned area 3 years after the fire. Because snowshoe hares were t a very high population level, they consumed large quantities f willow sprouts and charred bark during the fall and winter fter the fire. Hare population levels stayed high until 1974, hen they dropped precipitously. During the study period, the nowshoe hare population varied from a high of six hares per ectare in the fall of 1971 to a low of 0.12 hare per hectare in he spring of 1975.

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INTRODUCTION[1]

In interior Alaska, fire is an extremely important environmental factor. The varied array of forest communities--with paper birch (*Betula papyrifera* Marsh.), aspen (*Populus tremuloides* Michx.), black spruce (*Picea mariana* (Mill.) B.S.P.), and white spruce (*Picea glauca* (Moench) Voss) as principal tree components--displays patterns over the landscape which, in almost every case, can be directly traced to the distribution of past fires. Also, as a result of repeated wildfires, stands of trees older than 170 years are rare, except on islands in major rivers, throughout most of the Alaska interior. Wildfire statistics indicate that over the past 30 years about 400 000 ha a year were burned (Barney 1971).

Early interest in Alaska wildfires concentrated mainly on investigating means of improving fire control technology. Beginning about 1970, however, increasing numbers of individuals and Alaska groups began to propose that wildfires might be beneficial in some cases. Some suggested that since wildfires started by lightning are a normal part of the taiga environment, areas should be designated where wildfires are allowed to burn and natural processes permitted to continue as in the past. Proponents argued that such a policy would reduce fire control costs, lessen environmental degradation caused by fire suppression activities, and increase the acreage of seral plant communities important to herbivores, such as moose. Choice of optimum fire management strategies for interior Alaska cannot be made, however, without sufficient quantitative information on the effects of wildfires on taiga ecosystems. Because this necessary information is not available, scientists at the Institute of Northern Forestry are attempting to gain a better understanding of the role of fire in the distribution, structure, and function of taiga ecosystems.

An important part of this effort has been intensive study of an area on Wickersham Dome burned over by a 1971 wildfire. A multidisciplinary study was initiated soon after the fire was controlled, in an attempt to assess the impact of the fire on biotic communities and their environments. Scientists representing several disciplines directed their talents to the study of as many abiotic and biotic factors as possible. The most intensive portion of this study extended through 1973, although certain portions of the study are still continuing.

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[1] This section was prepared by C. T. Dyrness, Supervisory Soil Scientist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

DESCRIPTION OF STUDY AREA[2]

The Wickersham Dome research area is located about 50 km northwest of Fairbanks, adjacent to the Elliott Highway (fig. 1). It is situated within the Yukon-Tanana Uplands physiographic province, an area of relatively gentle relief with rounded ridges oriented in a northeast-southwest direction. Elevations range from 210 m at the lowest level along Washington Creek to 980 m at the summit of Wickersham Dome. The area lies within the boundaries of the Pipeline Corridor Reserve designated by the Bureau of Land Management, U.S. Department of the Interior.

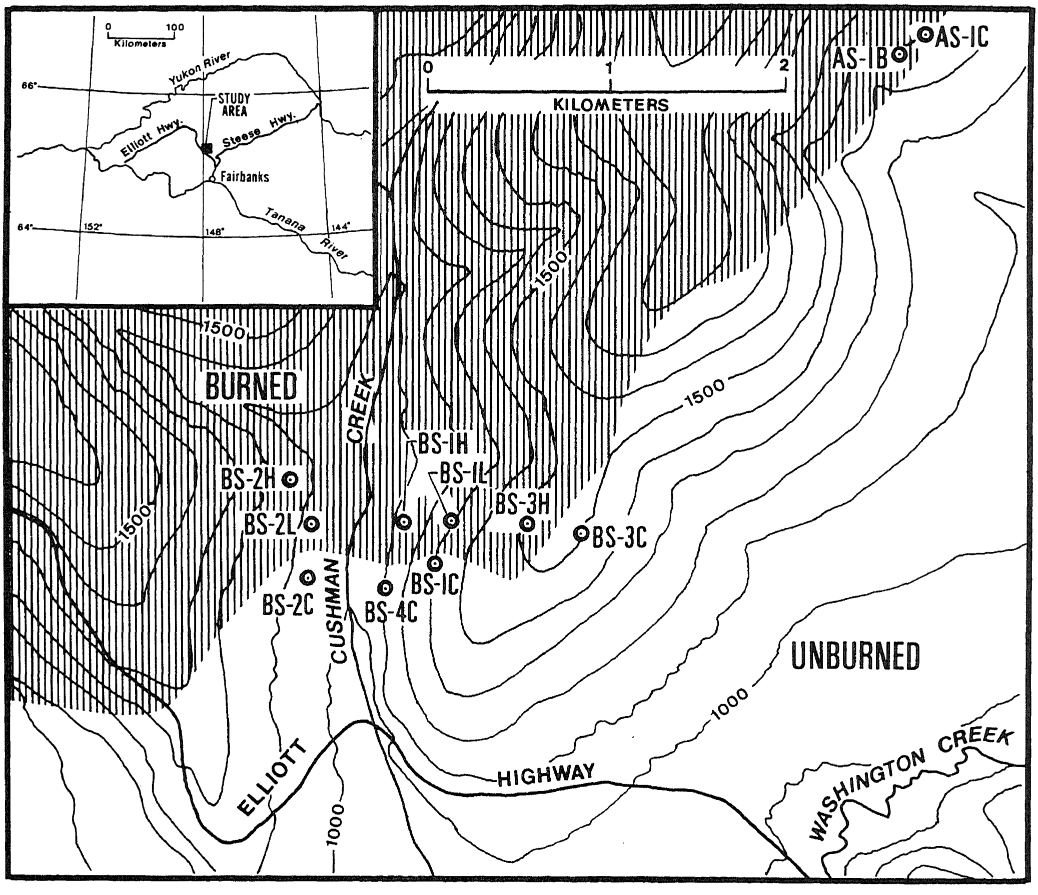

Figure 1.--Location of Wickersham Dome fire and sampled stands.

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[2] Description prepared by C. T. Dyrness, Supervisory Soil Scientist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Geologically, the area is characterized by Precambrian schist and gneiss bedrock which has not been modified by glaciation. Except at highest elevations, bedrock is mantled by a layer of wind-deposited loess. The study area lies within the zone of discontinuous permafrost. Ridgetops and upper south slopes tend to be free of permafrost. In other locations, however, permafrost is generally about 40 to 50 cm below the surface. Mineral soils are silt loam in texture and are mantled by organic materials (mostly mosses and litter) approximately 20 to 50 cm thick.

Before the 1971 wildfire, the area was mainly covered with black spruce stands, ranging in age from 50 to 125 years, depending on fire history. Stands were open, dominated by slow-growing black spruce 6-10 m in height and 8-12 cm in diameter, and interspersed with occasional paper birch and scattered large willow (mostly *Salix scouleriana* Barratt) and alder (*Alnus crispa* (Ait.) Pursh) shrubs. The most conspicuous vascular plants in the understory were low shrubs, such as Labrador-tea (*Ledum groenlandicum* Oeder), bog blueberry (*Vaccinium uliginosum* L.), mountain-cranberry (*Vaccinium vitis-idaea* L.), and prickly rose (*Rosa acicularis* Lindl.). A nearly continuous moss cover was present, made up of feather mosses, with some *Sphagnum*. Lichens were also conspicuous components of the ground cover, primarily *Cladonia* and *Peltigera* species. Stands of quaking aspen occurred on some slopes and were characterized by a striking decrease in moss cover in the understory.

The fire, ignited by lightning on June 24, 1971, started near Wickersham Dome. Bureau of Land Management personnel made an all-out effort to control the fire--775 people, 29 bulldozers, 6 pumps, 4 tankers, and 4 helicopters--but the fire proved difficult to control because of low fuel moisture and generally brisk breezes. The fire burned in a southwesterly direction and was finally stopped on June 30, but only after 242 000 liters of retardant had been aerially dropped. General outline of the burned area is shown in figure 1.

Burned area totaled 6 313 ha, of which 5 100 ha were Federal and 1 213 ha were State or privately owned. Expenditures for control totaled $1,099,479; damages to timber, recreation, soil, grazing, and wildlife resources were estimated at $655,200 (Noste and Davis 1975).

Weather conditions at the time of ignition on June 24 were conducive to fast rates of fire spread, contributing to the failure of initial attack. The maximum reported temperature of 30°C, combined with a calculated 2.5-percent fine fuel moisture and 6 m/s wind, yields a spread index of 70 (table 1)--a value exceeded less than 1 percent of the time, based on Fairbanks records (Barney 1967). Conditions on June 25 and 26 had a similarly high potential for fire, except the wind was much lower--only 3 m/s. The spread index was 43 and 42 on June 25 and 26; these are exceeded only about 20 percent of the time. On June 27, windspeed increased again, yielding a spread index of 58, a value exceeded less than 5 percent of the time. By this time the head of the fire had reached a ridgetop between Washington Creek and

Table 1--Weather conditions at Fairbanks during the Wickersham Dome fire, 1971

June	Maximum temperature	Relative humidity	Fine fuel moisture	Windspeed	Direction	Spread index	Buildup index
	°F	- - -Percent- - -		Miles per hour			
24	86	15	2.5	14	N	70	128
25	85	17	3.0	7	N	43	133
26	84	19	3.5	7	NE	42	138
27	84	20	3.5	12	N	58	143
28	75	24	5.0	13	NE	60	146
29	62	32	6.5	14	E	54	149
30	58	52	11.0	6	NE	23	150

the Chatanika River, and the rates of spread decreased substantially. The days on which the fire burned, being so near the summer solstice, had very short nights with little time for recovery of moisture in the fine fuels.

The buildup index, a measure of moisture content in the heavier fuels, is a relative indicator of the potential intensity of the fire. Historically, values of 128 are exceeded about 3 percent of the time during the fire season in the fire area. Burning conditions, as indicated by the spread and buildup indexes, were quite severe at the time of ignition and during the major part of the time the fire was spreading.

Bulldozers constructed about 113 km of fireline which averaged 12 m in width. Because much of the area is underlain by permafrost, erosion was rapid when the insulating mat of organic materials was removed. Soon after the fire, it was estimated that at least 75 percent of dozer-constructed firelines needed rehabilitation to prevent or slow erosion. By July 4, 1971, melting of exposed permafrost had proceeded to such an extent that it was causing considerable erosion and siltation of Washington Creek. Therefore, an extensive program of tractor-construction of water bars and diversion ditches on firelines was begun immediately. In addition, during the following April (1972), firebreaks were aerially sown with grass and fertilized. The seed mixture consisted of Manchar smooth brome (37.5 percent), creeping red fescue (37.5 percent), and Rodney oats (25 percent), applied at a a rate of 45 kg/ha. Also aerially applied were 336 kg/ha of pelleted 10-20-20 fertilizer.

SELECTION OF STUDY PLOTS[3]

In August 1971, we selected sites for intensive study of the effects of fire in black spruce stands. We intended to secure three sets of plots, each containing three plots--an unburned stand (control--called the unburned control), a lightly burned stand, and a heavily burned stand; however, for one set of plots, only a heavily burned stand was available besides the unburned control.

Criteria used for evaluation of the intensity of the burn were:

> Lightly burned--less than 50 percent of the ground surface blackened; lesser vegetation not consumed; branchlets present on trees and crowns scorched but not consumed.
>
> Heavily burned--more than 90-95 percent of the area blackened; lesser vegetation and tree crowns consumed.

We did not attempt to evaluate stands with 50-90 percent of the area blackened.

The three sets of plots selected were along a generally east-west transect across the burned area. All were in areas of black spruce. Plot set 1 was located between 335 and 396 m in elevation. This set of plots was on a west-facing slope with a gradient of 12-20 percent and consisted of an unburned control plus a lightly burned and a heavily burned stand. Plot set 2, consisting of an unburned control and a lightly burned and a heavily burned stand, was located at approximately 335-m elevation on a gentle, east-facing slope. Plot set 3 was located at an elevation of approximately 468 m on the nearly flat crest of a ridge; slopes, having a generally western aspect, were 0 to 5 percent. Plot set 3 consisted of only two stands, an unburned control and a heavily burned stand. Examples of the three conditions are shown in figures 2, 3, and 4.

During the summer of 1972, three additional plots were established. A set of two plots (plot set 4)--one heavily burned (fig. 5) and the other an unburned control--was located in an area of aspen at an elevation of approximately 510 m at a midslope position; slopes were 13-15 percent, and aspect was dominantly south. In addition, another unburned stand, situated on a lower portion of the slope (at an elevation of 335 m), was added to plot set 1 as a control for the nearby heavily burned plot. Characteristics of all the plots are summarized in table 2.

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[3] This section was prepared by C. T. Dyrness, Supervisory Soil Scientist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

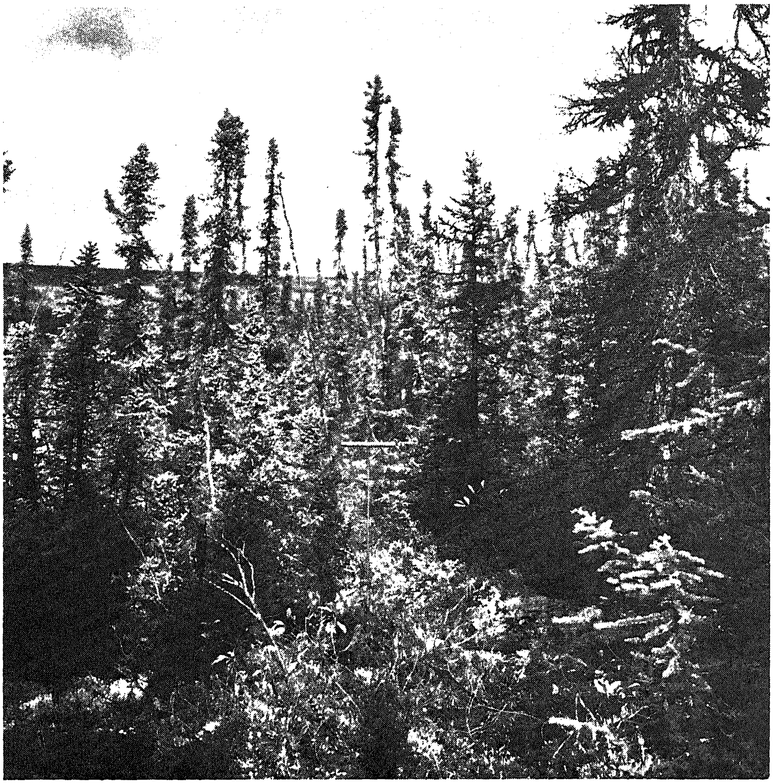

Figure 2.--General view of unburned black spruce stand.

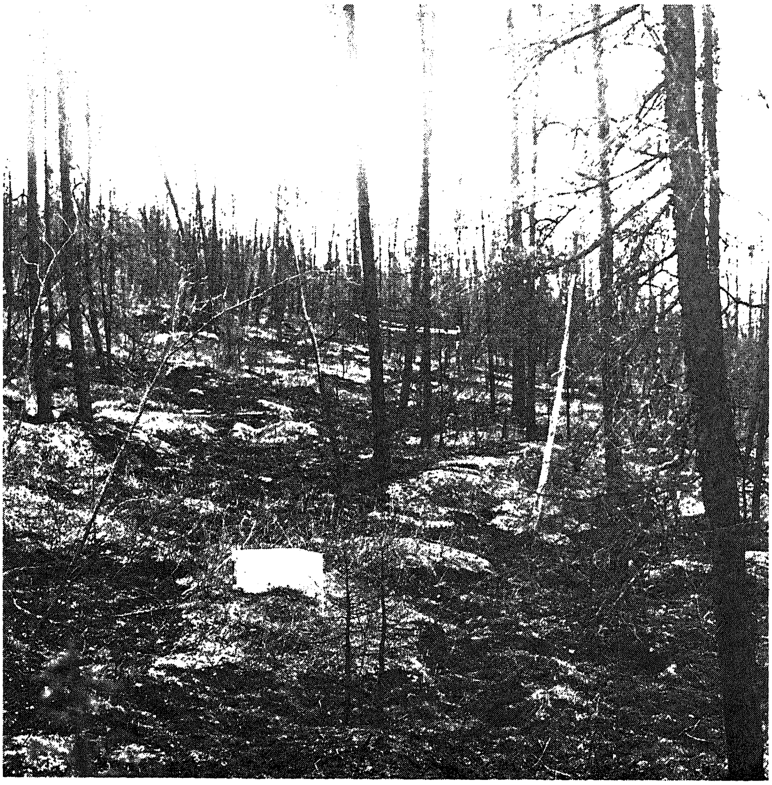

Figure 3.--Lightly burned stand (BS-1L), showing typical ground cover remaining after the fire.

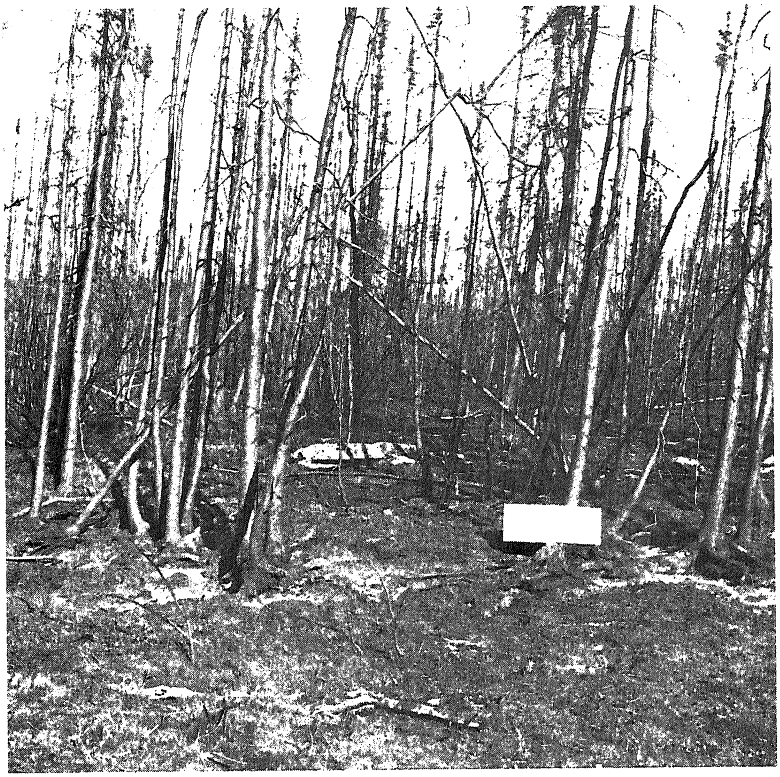

Figure 4.--General condition of heavily burned stands is shown here by stand BS-3H. Light color in background is unburned but killed Sphagnum moss mound.

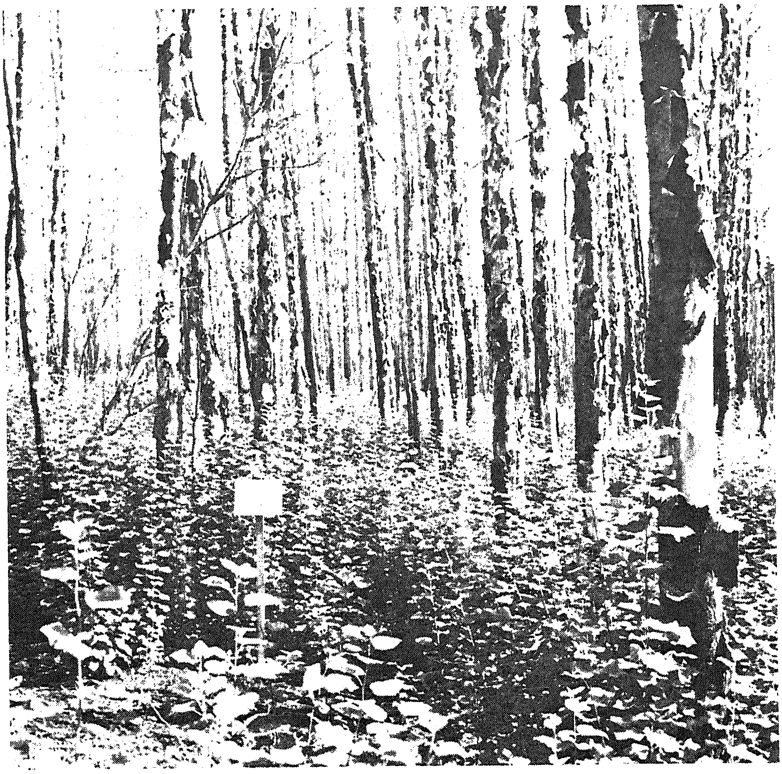

Figure 5.--View of burned aspen stand in August 1972 (AS-1B) shows development of aspen sucker shoots. Note how snowshoe hares removed the charred bark during the 1971-72 winter.

Table 2--Physical description and burn intensity of 11 stands after the Wickersham Dome fire

Plot set	Stand	Slope	Aspect	Elevation	Slope position	Burn intensity	Year of establishment
		Percent		Meters			
1	BS-1C	20	West	396	Middle	Control	1971
1	BS-1L	15	West	396	Middle	Light	1971
1A	BS-1H	12	West	335	Lower	Heavy	1971
1A	BS-4C	12	Southwest	335	Lower	Control	1972
2	BS-2C	5	Southeast	335	Lower	Control	1971
2	BS-2L	10	East	335	Lower	Light	1971
2	BS-2H	12	East	335	Lower	Heavy	1971
3	BS-3C	0	Level	468	Ridgetop	Control	1971
3	BS-3H	5	West	468	Ridgetop	Heavy	1971
4	AS-1C	13	Southwest	518	Middle	Control	1972
4	AS-1B	15	South	503	Middle	Heavy	1972

ABIOTIC FACTORS

The Soil

General description of soils in the study area[4]

Soils in the Wickersham Dome area are formed in a layer o
wind-deposited silty materials (loess) over weathered mica s
bedrock of the Birch Creek formation. The loess mantle varie
in thickness from a few centimeters on steep slopes and ridge
to over a meter on lower slopes and valley bottoms. Since th
is an area of discontinuous permafrost, soils frequently lack
permafrost on ridgetops and south-facing slopes, but shallow
permafrost is present in soils on north-facing slopes and val
bottoms. Soils with a shallow permafrost table are marked by
deep (up to 50-cm), overlying layers of moss and litter and a
continuously wet profile throughout the growing season.

During the summer of 1974, C. E. Furbush and D. B. Schoeph
soil scientists with the U.S.D.A. Soil Conservation Service,
mapped the soils over most of the fire area. They identifie
soil series in the area--Ester, Fairplay, Gilmore, Goldstrea
and Saulich. The Ester, Fairplay, and Saulich series occur
the plot areas and therefore we will describe them in some de

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[4] Description prepared by C. T. Dyrness, Supervisory Soil Scientist,
Forest Service, Pacific Northwest Forest and Range Experiment Station, In
tute of Northern Forestry, Fairbanks, Alaska.

The Gilmore series is restricted to upper slopes and ridgetops an consists of well-drained, permafrost-free soils formed in a shall loess mantle over gravelly silt loam derived from the underlying weathered schist. Soils classified in the Goldstream series are poorly drained, silty soils that occur in valley bottoms. These soils typically have a shallow permafrost table and are therefore wet throughout the summer.

According to results of the soil survey, plots making up plot set 1 are situated on two soil series--the Ester and the Saulich. Fortunately, each soil has both a burned stand and an unburned control.

One unburned control and a lightly burned stand are in an area of Ester silt loam, a poorly drained soil that occurs on north-facing slopes. These soils are generally shallow to both permafrost and bedrock (silt mantle is generally less than 50 cm thick Ester soils typically have a thick moss and litter surface layer over mottled dark grayish-brown silt loam or gravelly silt loam; amounts of gravel increase with depth. The permafrost table is generally within 25 cm of the surface of the mineral soil, and the soil above the frost line is invariably wet. Where bedrock is shallow or the surface organic layer is thin, permafrost may be lacking above the rock.

The heavily burned stand and the unburned control in plot set 1 are situated on Saulich silt loam soils which, in many respects, resemble Ester soils but are formed in deeper loess deposits on lower slopes. Saulich soils are poorly drained, have shallow permafrost layers, and are generally very moist to wet. They are formed in silt loam deposits more than 75 cm thick. A typical Saulich profile has a moss-litter layer 25-30 c thick, underlain by 10 cm of very thick, very dark grayish-brown silt loam A1 horizon, over a frozen B1 horizon made up of mottled olive gray silt loam.

All three stands in plot set 2 are also located on Saulich silt loam soils.

Plot set 3, consisting of an unburned control and a heavily burned stand situated on a ridgetop, is in an area of soil classe as Fairplay silt loam. These soils are moderately well drained to somewhat poorly drained and are characteristic of upper slopes and ridgetops. Permafrost, if present, is at substantial depths (at least 150 cm). Fairplay soils typically have a relatively thin organic layer over mottled dark grayish-brown gravelly silt loam which varies from 50 to 100 cm in thickness over schist bedrock. Gravel content, made up of angular schist fragments, ranges from very little to 35 percent by volume.

Unfortunately, the two plots in the area of aspen were not within the soil survey area. Therefore, the soils in that area have not been described and classified.

Soil taxonomic units at the suborder level for the Saulich and Ester series is Histic Pergelic Cryaquept and for Fairplay, Aquic Cryorthent.

Effects of burning on forest floor characteristics[5]

One of the outstanding characteristics of taiga soils is the thick organic layer which generally overlies the mineral soil. These layers, mainly comprised of organic matter produced by mosses and lichens, as well as vascular plant litter, are especially thick under black spruce stands, where they may reach depths of 50 cm or more. The degree to which these layers are consumed by fire controls, to a large extent, characteristics of the postfire community. Site factors greatly influenced by depth of burning in the organic layer include soil temperature and thickness of the active layer, levels of available soil nutrients and subsequent rates of mineralization, and condition of the seed bed during initial stages of secondary succession. The amount of mineral soil exposed as a result of burning is an especially important consideration because it offers the most suitable seed bed for germination of all species of Alaska taiga trees and most of the shrubs (Viereck 1973).

In the Wickersham Dome study area, observations of forest floor characteristics in both burned and unburned stands were conducted during the fall of 1971. At 20 points within each of eight stands, a 15-cm-diameter core of the forest floor was removed, including organic material as well as a portion of the mineral soil. After the cores were separated into mineral and organic components, the organic portion was taken to the laboratory, ovendried, and weighed. The depth of the organic layer was measured on the side of the hole after the core was removed. Data for each plot were summarized by total thickness, weight, and bulk density of the organic layer.

The data were analyzed for differences between location and intensity of burn. The statistics are intended for descriptive purposes for an understanding of the magnitude of the observed effects rather than conclusive inferences from the data. The only statistically significant difference in the thickness of the layer was between the heavily burned stand and the unburned control in plot set 1.

Examination of organic layer thicknesses (table 3) indicates that plot set 3, on the ridgetop, had a much thinner litter and moss layer; and less litter (1.0 cm) was removed by the fire. In plot set 2, comparisons of the burned stand with the unburned control indicate reductions of 3.35 cm in thickness of the forest floor in the heavily burned stand and 1.90 cm in the lightly burned stand. Stands in plot set 1 had the thickest organic layers, and more material was apparently consumed by the fire.

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[5] This section was prepared by N. V. Noste, Fire Scientist, and R. J. Barney, Fire Scientist, Forest Service, U.S. Department of Agriculture, Northern Forest Fire Laboratory, Missoula, Mont.; and K. P. Burnham, Biometrician, Fish and Wildlife Service, U.S. Department of the Interior, Western Energy and Land Use Team, Fort Collins, Colo.

Table 3--Thickness, ovendry weight, and bulk density of forest floor layers in 8 burned stands and unburned controls in the Wickersham Dome fire study area[1/]

Plot set, slope, and treatment	Total thickness		Weight		Bulk density	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	- -Centimeters- -		- - -Grams- - -		Grams per cubic centimeter	
Plot set 1, west-facing slope of 12-20 percent:						
Unburned control	28.70	6.95	220.90	57.10	0.043	0.011
Lightly burned	23.00	6.71	224.10	66.64	.056	.020
Heavily burned	18.40	4.29	346.05	260.61	.104	.075
Plot set 2, very gentle, east-facing slope:						
Unburned control	21.45	3.77	290.25	81.73	.077	.028
Lightly burned	19.55	5.73	297.20	121.00	.093	.057
Heavily burned	18.10	3.46	287.35	126.36	.088	.041
Plot set 3, ridgetop:						
Unburned control	13.90	5.80	308.70	117.90	.136	.062
Heavily burned	12.95	4.38	249.60	94.85	.109	.039

[1/] Each value represents the mean of 20 measurements.

After the fire, the difference in thickness of the forest floor between the unburned control and the heavily burned stand was 10.30 cm; the difference between the lightly burned stand and control was 5.70 cm. Differences among all three treatments in plot set 1 were found to be statistically significant (table 3).

A statistically significant interaction exists between location and intensity. A pattern of consistently less reduction in forest floor thickness from the lower stands (plot set 1) toward the ridgetop can be recognized. More reduction of the organic layer progressing from the light to the heavy intensity burn may also contribute to the significant interaction.

Apparently because of the extreme variability in weight values, neither the light nor the heavy burns removed sufficient organic material to consistently show a significant weight loss; and there was no apparent difference in weight relative to burn intensity. The extreme variability in forest floor weights may have been at least partially caused by the difficulty encountered in obtaining a clean separation between organic and mineral soil. Because of this, the organic layer samples were contaminated by variable amounts of mineral soil particles.

In summary, it appears that the Wickersham Dome fire removed only relatively small portions of the forest floor material. Although comparisons of depths of organic layers in burned areas with those in the unburned controls consistently indicated reductions with burning, in two out of five instances these differences were not statistically significant. The greatest reduction in forest floor thickness occurred on plots having the thickest layers, and even here the heavily burned layer was almost two-thirds as thick as that in the unburned control.

Mineral soil characteristics following burning[6]

Most studies of fire and soil relationships have shown that burning may have significant effects on mineral soil properties especially in intense fires, the fertility of the surface soil often altered considerably. In temperate regions of the United States, changes resulting from burning generally indicate reduce quantities of organic matter, nitrogen, and in some instances, phosphorus, but significantly increased amounts of exchangeable cations, such as potassium, calcium, and magnesium, as well as a increase in soil pH (Dyrness 1963). Lutz (1956) in Alaska and Scotter (1971) in northern Canada, however, reported an increase not only in exchangeable calcium and potassium but also in nitro gen and phosphorus after fire. The increased amounts of nitroger and phosphorus in the taiga probably represent a fire-generated release of these elements to the mineral soil from deep, overlyi organic layers. In more temperate regions, forest floor layers are usually not as thick.

To determine possible effects of the Wickersham Dome fire on soil properties, we analyzed samples of mineral soil in the lab tory. These samples were collected in the fall of 1971 concurrently with the organic layer samples and consisted of cores 15 in diameter, which included the upper 15 cm of the mineral soil In each of the 11 plots (9 in black spruce and 2 in aspen) 20 samples were collected; 4 from each plot were randomly selected for soil analysis. Laboratory determinations included particle size distribution; pH; cation exchange capacity; exchangeable potassium, calcium, and magnesium; available phosphorus; and to nitrogen.

Results of soil analyses are shown in table 4. For purposes of comparison, data are grouped by plot sets, and each set cont at least one unburned control plot as well as a nearby burned p (table 2).

Close inspection of the results reveals a high degree of variation among the plots, especially in chemical properties (tabl Because of this, it is impossible to discern any consistent differences in soil properties between the burned stands and unbur controls. There are several possible reasons for this lack of correlation. The first, and perhaps the most important, is the depth of mineral soil sampled (15 cm). Since the most pronounce effects of burning would be expected in the surface 2-3 cm of s the sampling procedure may have effectively masked differences a the surface of the mineral soil. In addition, inherent soil variability may be sufficient in this area to preclude the possibil

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[6] This section was prepared by N. V. Noste, Fire Scientist, and R. J. Barney, Fire Scientist, Forest Service, U.S. Department of Agriculture, Northern Forest Fire Laboratory, Missoula, Mont.; and C. T. Dyrness, Supervisory Soil Scientist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Table 4--Results of analyses of samples of the 0- to 15-cm layer of mineral soil for 11 stands after the 1971 Wickersham Dome fire[1]

Plot set and treatment	Sand	Silt	Clay	Textural class[2]	pH	Cation exchange capacity	Exchangeable						Available P	Total N
							K		Ca		Mg			
	- - -Percent- - -					meq/100 g	p/m	meq/100 g	p/m	meq/100 g	p/m	meq/100 g	p/m	Percent
BLACK SPRUCE														
Set 1:														
Unburned control	18.85	67.95	13.20	Si.Lo.	4.12	41.24	0.980	0.25	7.417	1.85	1.865	0.77	1.5778	0.45041
Lightly burned	23.20	65.32	11.48	Si.Lo.	4.22	32.83	.853	.22	6.634	1.66	1.526	.63	1.6474	.38365
Unburned control[3]	11.45	77.07	11.48	Si.Lo.	4.52	24.81	.830	.21	16.410	4.09	2.894	1.19	3.2133	.26790
Heavily burned	31.81	55.45	12.74	Si.Lo.	4.82	14.89	.596	.15	15.187	3.79	2.208	.91	2.7134	.16747
Set 2:														
Unburned control	7.13	81.21	11.66	Si.	5.09	34.59	.910	.23	31.078	7.75	3.150	1.30	2.6412	.28676
Lightly burned	19.33	73.63	7.04	Si.Lo.	4.66	19.78	.634	.16	11.956	2.98	2.762	1.14	2.7569	.18583
Heavily burned	9.33	79.35	11.32	Si.Lo.	4.93	31.18	1.054	.27	31.811	7.94	2.772	1.14	4.3714	.31804
Set 3:														
Unburned control	11.71	74.34	13.95	Si.Lo.	4.93	12.86	.956	.24	5.389	1.34	1.304	.54	3.4128	.06779
Heavily burned	11.45	74.59	13.96	Si.Lo.	4.73	21.68	1.226	.31	10.035	2.50	2.420	1.00	2.6072	.16791
ASPEN														
Set 4:														
Unburned control	24.34	63.56	12.10	Si.Lo.	3.84	29.17	1.361	.35	7.892	1.97	1.397	.57	12.7320	.31914
Heavily burned	14.08	71.67	14.25	Si.Lo.	4.00	22.26	1.807	.46	6.561	1.64	1.585	.65	15.9896	.20924

[1] Each value represents the mean of 4 determinations.

[2] Si.Lo. = silt loam: Si. = silt.

[3] Plot added in 1972.

of successfully characterizing the effects of burning on the basis of such a comparatively small sample. If this is the case, measurements of samples collected from the same location before and after burning would be much more likely to reflect the actual effects of fire.

Although the effects of burning on the soil samples are not apparent, the data do reflect certain differences (table 4). Perhaps the most striking is the appreciably higher amounts of available phosphorus in soils under aspen. This is not surprising; it is well known that aspen litter contains much larger quantities of phosphorus than does spruce litter (Rodin and Bazilevich 1967). Other differences, apparently also a function of plot location, are noticeable. For example, soil from the unburned control on the ridgetop (plot set 3) has a considerably lower total nitrogen content and is also lowest in cation exchange capacity and exchangeable calcium and magnesium.

On the basis of these results, we recommend that mineral soil samples be collected in depth increments of 2-3 cm at many locations in future studies of fire effects. In addition, sampling should be done at intervals after the fire so the redistribution of mobilized elements by leaching or other processes can be followed.

Effect of burning on soil temperature[7]

One of the important changes taking place in the soil after fire is modification of temperatures. Because of the increase in surface absorption of solar heat, the reduced thickness of the organic layer, and the lack of surface vegetation, temperatures tend to be warmer in a burned soil than in an unburned soil.

To compare soil temperatures in the burned and unburned stands in plot set 3 (table 2), we installed a series of thermistors at the following depths: forest floor surface, 5 cm in the organic layer, organic-mineral soil interface, 10 cm below mineral soil surface, 20 cm below mineral soil surface, and 50 cm below mineral soil surface.

These temperatures were recorded once a week about noon throughout the year.

Graphs for soil temperatures at 5 cm in the organic layer and at the 10- and 50-cm depths in the mineral soil are shown in figures 6, 7, and 8.

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[7] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

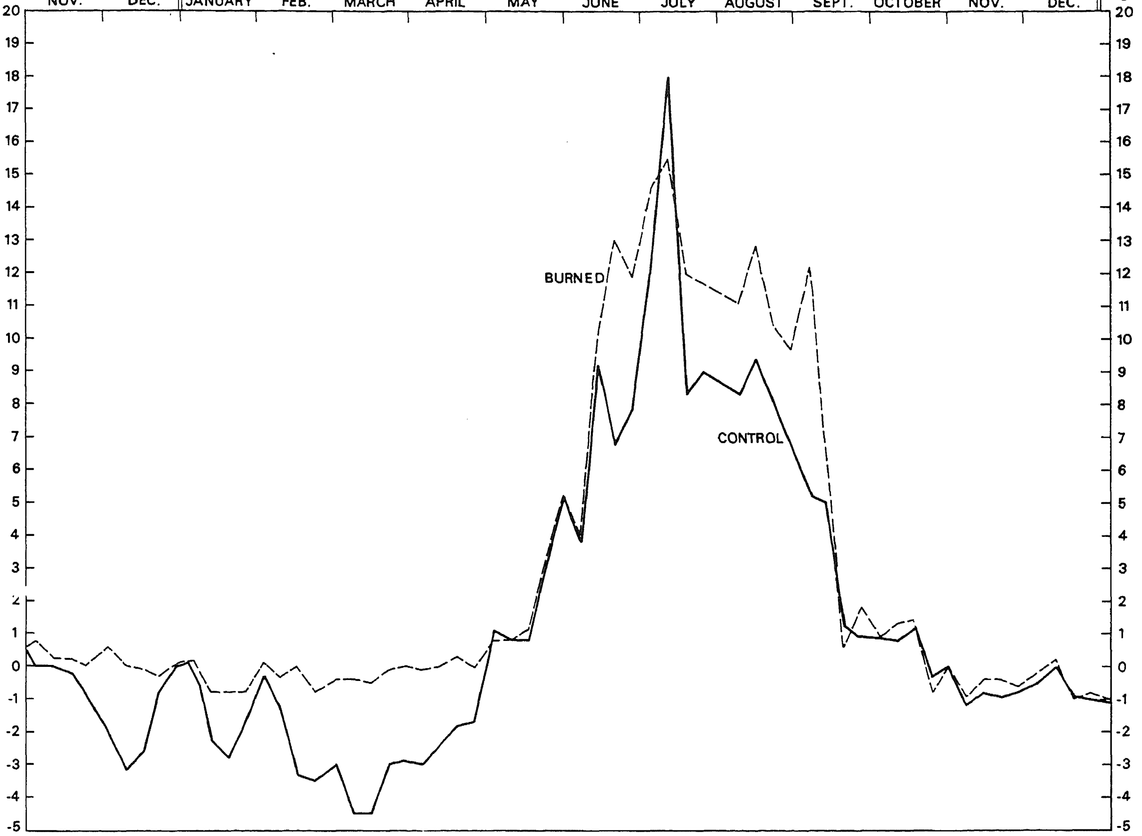

Figure 6.--Soil temperature at a depth of 5 cm in the organic layer at burned and unburned control sites during the 1st year after burning.

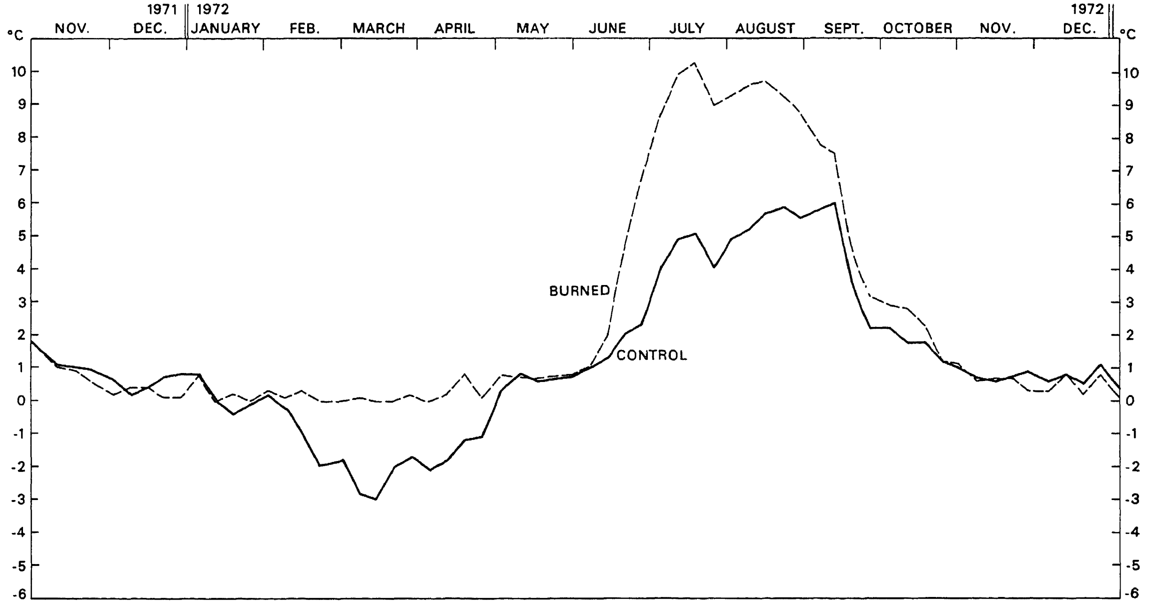

Figure 7.--Soil temperature at a depth of 10 cm in the mineral soil at burned and unburned control sites during the 1st year after burning.

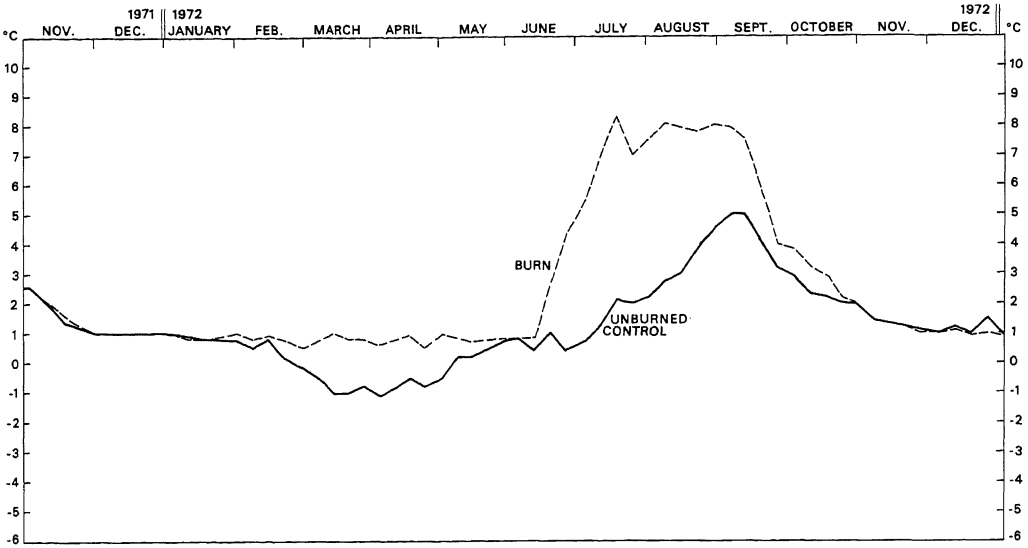

Figure 8.--Soil temperature at a depth of 50 cm in the mineral soil at burned and unburned control sites during the 1st year after burning.

For the 10-cm depth (fig. 7), temperatures during the fall of 1971, the same year as the fire, were similar in burned and unburned areas until the end of January. During February and until mid-March, temperatures continued to decline in the unburned stand until a low of -3°C was reached in mid-March. In the burned stand, temperatures remained close to 0°C until April 10. During May and early June, the temperatures at 10 cm in the mineral soil were similar. After the final melting of the overlying snow in mid-May to late May, there was a rapid rise in soil temperatures in the burned stand; a high of 10.5°C was reached on approximately July 20. The soil in the unburned control warmed much more slowly during the summer with a much greater timelag and did not reach its warmest point, 6°C, until September 13, long after the close of the active growing season and within a week of the first snowfall. During the cooling period in September and October, the rates were similar; but the burned stand remained warmer until the end of October, at which time the temperatures were once again about the same.

A comparison of the 10-cm soil temperature (fig. 7) with air temperature illustrates an interesting and well-documented timelag. Although the coldest air temperatures occurred the first 2 weeks in January, the soil temperatures at 10 cm did not reach the coldest point until 2 months later. Similarly, summer air temperatures were at a maximum in mid-June, but soil temperatures at 10 cm did not reach a maximum until July 20 in the burned area and the middle of September in the unburned control.

If the soil temperatures are compared with air temperatures, as snow melts we can see that, although air temperatures are well above the freezing point by mid-May, soil temperatures do not begin to rise above 0°C until all the snow is melted.

In the fall of 1972 the permanent snow cover came while soil temperatures were relatively warm. This may have resulted in the rapid cooling in the organic layer in mid-September. On the other hand, the snow cover seems to have insulated the soil from the effects of the cold period in late October.

Figures 6 and 8 show soil temperatures for the 5-cm depth in the organic layer and for the 50-cm depth in mineral soil. As would be expected, the litter layer shows a much wider fluctuation of temperatures. Some of the same patterns as occurred at the 10-cm depth in the mineral soil, however, are apparent. A surprising fact is that, during most of the summer soil temperature for the organic layer in the burned stand were 2°-4° higher than in the unburned control (fig. 6), but at the time of the highest temperature in July the temperature in the organic layer beneath living mosses in the unburned control was greater than that in the burned forest floor with a charred surface.

As expected, mineral soil temperatures at a depth of 50 cm showed less fluctuation and range than those at 10 cm or in the organic layer (fig. 8). Also, the timelag was longer, the minimum temperature occurred in April, and no warming occurred until after mid-June in the burned stand and mid-July in the unburned control.

Temperature-sensitive pellets were placed on the surface of the blackened, burned organic material on June 15, just after the hottest days of the summer. During the week of June 15-22, the temperature reached at least 59°C. During July, the highest surface temperatures were between 55°C and 50°C; and by August they were between 48°C and 55°C. Surface temperatures as high as those in June are considered lethal to tree seedlings.

Permafrost[8]

An important effect of wildfire in the taiga of Alaska is alteration of the thickness of the active layer (thawed soil above the permafrost layer). Few data are available for thickness of the active layer after fire in forest stands in Alaska, but the active layer generally is known to be thicker in successional stands after fire than it is in unburned black spruce forests. The actual heat produced by the fire is probably unimportant, as the organic layer seldom burns to the permafrost boundary. Brown (1965) stated, "A fire may burn trees, brush, and even the surface of the moss without altering the underlying permafrost." After a fire, however, the changes in the surface albedo and the removal of the vegetation and some of the organic mat result in warmer soils and deeper thawing. After a fire in the black spruce type at Inuvik, in Northwest Territories, Canada, Hegginbottom (1971) reported that by the summer after the fire, the thaw was 9 cm deeper in burned than in unburned stands. From eight permanent points on the Inuvik fire, Mackay (1970) reported an average increase of thaw of 24.1 cm (149 percent) by the end of the first summer after the fire and 24.8 cm (171 percent) by the end of the second summer. Cody (1964) reported that 3 years after a taiga fire in the Reindeer Grazing Reserve on the Mackenzie Delta, the permafrost had receded to a depth of 40 cm or more, and the recession of the ice had caused surface subsidence which resulted in a hummocky terrain.

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[8] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

At the end of the first summer after an August and September burn in eastern Alaska, Lotspeich et al. (1970) found no significant difference in thaw depth--both burned and unburned stands had thawed to approximately 70 cm. In an *Eriophorum* tussock tundra within the taiga of Alaska, Wein (1971) reported a 130- to 150-percent increase in the active layer in early summer after a fire the previous year, but only 115- to 120-percent difference by the time of maximum thaw in the fall. Brown et al. (1969) reported an increased thaw of 160 and 140 percent 4 years after a fire in a black spruce/*Eriophorum* tussock type in eastern Alaska. They also reported a 141- and 152-percent increase in thaw depth in a 1-year-old burn in an *Eriophorum* tussock type with scattered black spruce in central Alaska.

At the northern limit of forest vegetation in Russia, however, fire may result in a thickening of the active layer, followed in a few years by a rise in the permafrost upper surface. Kryuchkov (1968) reported that fire first caused a thawing of the upper permafrost layers with a resultant release of moisture, creating conditions which stimulated the growth of the *Eriophorum* cover. As a result of the insulating effects of the thicker vegetation mat, the active layer was only 40-45 cm thick a few years after the fire, whereas before the fire it had been 50-70 cm.

At Wickersham Dome we studied the annual freezing and thawing cycles and the depth to permafrost by three methods:

1. Weekly readings of soil temperature at two sites, one in a heavily burned stand and one in an unburned control at the ridgetop site (plot set 3).

2. Frost tubes filled with sand and a fluorescein dye (Rickard and Brown 1972) were installed in six stands, three burned stands and three unburned controls.

3. Probe lines were established so we could follow the recession of the frostline in burned stands, unburned controls, and the firelines; 10 probes were taken at each site and average depth to frozen soil was recorded.

We used the frost tubes to follow the freezing in the fall and winter, but the probe lines were better for following the thaw during the summer.

Because of the variation in depth to bedrock and depth to which frost tubes could be installed, general comparisons between all the burned stands and unburned controls were impossible. Instead, observations of permafrost were concentrated on three stands on organic soils near Cushman Creek: a heavily burned black spruce stand (BS-1H), its unburned control (BS-4C)--plot set 1A in table 2, and an adjacent heavily bulldozed fireline.

In the fall of the first summer after the fire, there was no significant difference between burned stands and unburned controls. Probing in four stands in the burn showed thaw to an average depth of 44 cm, whereas in the adjacent unburned controls the average thaw was to 47 cm.

Figure 9 shows the freeze-thaw cycle in a heavily burned stand and an unburned control for the 1st year after the fire. In the fall after the fire, there was no significant difference in the depth of the thaw (40 cm in the unburned control and 41 cm in the heavily burned stand). During the first winter after the burn, freezing occurred more rapidly in the unburned control than in the burned stand. The active layer was completely frozen by December 12 in the unburned control but not until January 15 in the burned stand.

The next summer, thawing was deeper in the burned stand than in the unburned control. Although the snow melted 2 weeks earlier in the burned stand than in the unburned, thawing was similar in both until June 7; after that, thawing was more rapid in the burned stand. Thawing to nearly the maximum depth of 63 cm had occurred by August 23 in the burned stand and to a maximum of 40 cm by September 6 in the unburned control. Thus, depth of thawing in the burned stand the first summer after the fire was 157 percent of that in the unburned control. Probing was also carried out in the fireline between the two stands. The rate of thaw during 1972 was more rapid in the fireline than in either the control or the heavily burned stand. Maximum depth of thaw in the fireline was 88 cm or approximately 200 percent of that in the unburned control.

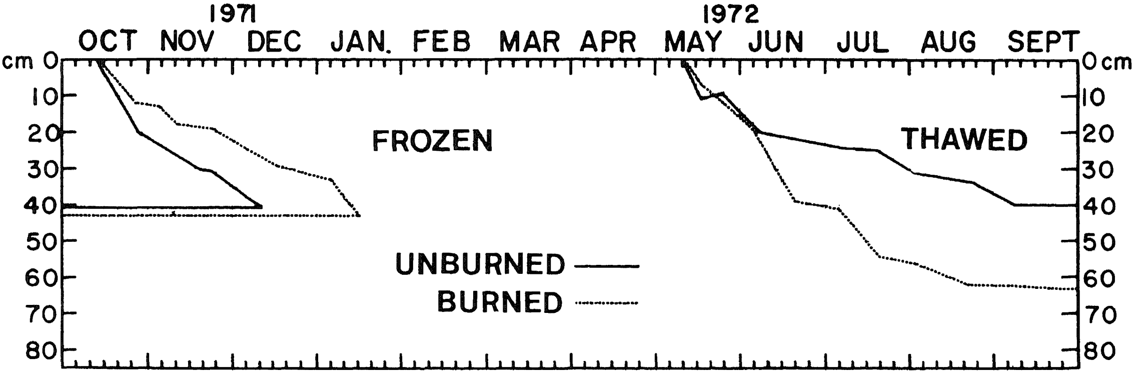

Figure 9.--Freeze-thaw cycle in a heavily burned stand and an unburned control for the 1st year after the fire. (Reproduced from: Viereck, Leslie A. 1973. Ecological effects of river flooding and forest fires on permafrost in the taiga of Alaska. In *North American contribution, permafrost, second international conference, p. 66. Natl. Acad. Sci., Washington, D.C.).*

Figure 10 compares the thawing depths in the heavily burne stands and the unburned controls and on the fireline for the 3 years after the fire. In the unburned control the thaw pat are similar each year; maximum thaw depth is approximately 45 Table 5 gives the depth of thaw in the three areas through th summer of 1976.

In the burned stand there has been an increase each year i maximum depth of thaw and in the rate of thaw (table 5).

The fireline has shown the most dramatic change in the dep thaw (table 5). In addition, there has been some subsidence the loss of pure ice deposits so that the actual depth of tha relationship to the original surface may be somewhat greater.

In the 5 years after the fire, there seemed to be no slowi down of the annual increase in thaw depth in either the burne stand or the fireline. With complete recovery of the surface vegetation, the depth of thaw is expected to stabilize and eve ally return to that of the original stand.

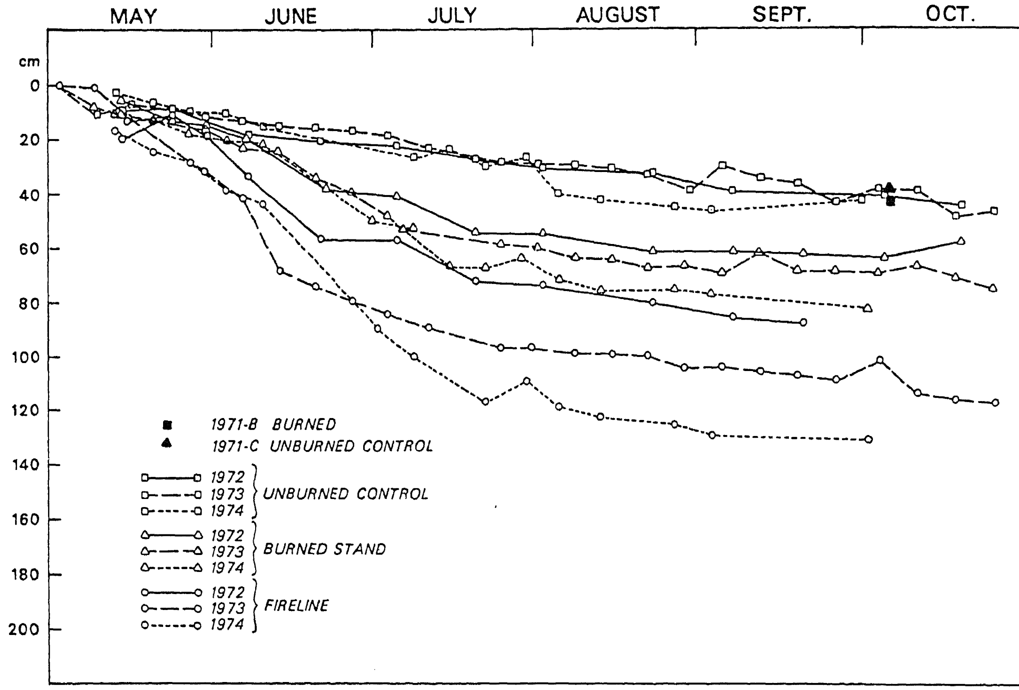

Figure 10.--Depth of thaw in a heavily burned stand, on a cleared fireline, and in an unburned control for 3 years after the fire.

Table 5--Maximum depths of thaw in an unburned control, a burned black spruce stand, and a fireline for the 6 summers after a June 1971 wildfire at Wickersham Dome

Stand and year	Maximum depth of thaw	Percent of thaw in unburned control	Annual increase in depth of thaw
	Centimeters	Percent	Centimeters
Unburned control:			
1971	40		
1972	42		
1973	45		
1974	45		
1975	45		
1976	38		
Burned in June 1971:			
1971	42	105	2
1972	62	148	20
1973	78	173	16
1974	81	180	3
1975	83	184	2
1976	109	286	26
Fireline, June 1971:			
1971			
1972	83	198	
1973	119	264	36
1974	136	302	17
1975	155	344	19
1976	196	515	41

Climatic Factors[9]

Snow depths in burned and unburned forests.

Snow depths were recorded weekly in three burned black spruce stands (BS-3H, BS-1L, and BS-1H) and three unburned controls (BS-3C, BS-1C, and BS-4C) from two snow stakes in each stand. Figure 11 shows the snow depths for the two stands in plot set 3 (BS-3C and BS-3H) (table 2). These stands show a pattern that characterized all six of the sampled stands. In 1971 the first snow fell in late September and by October 14, when all stakes were read the first time, there was 12 cm of snow on the ground.

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[9] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and A. E. Helmers, Research Hydrologist (retired), USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

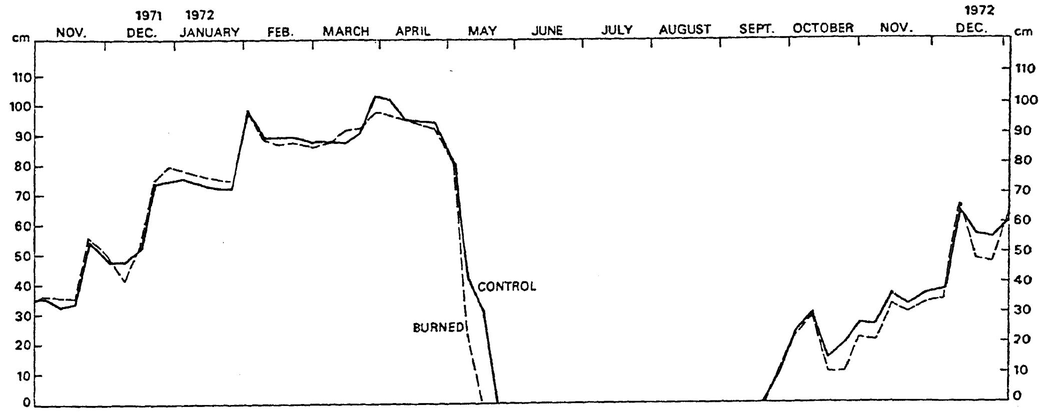

Figure 11.--Depths of snow on burned black spruce stands and unburned controls from November 1971 to December 1972, Wickersham Dome.

Major snowfalls and periods of settlement and compaction can be seen in the steplike curve from November 1 to March 29, the time of maximum snow accumulation (approximately 100 cm in each stand). During this period, there was no significant differenc in snow depths between the burned stands and unburned controls.

There was no appreciable snowmelt until the daily mean tempe ture rose above 0°C at the end of April. Melt was then extremel rapid so that by May 24 all snow was gone from both the unburne control and the burned stand. Snowmelt was much more rapid in the burned stand than in the control. On May 3 both stands had 80 cm of snow; by the following week, the snow in the burned stand had been reduced to 13 cm, whereas that in the unburned control was 42 cm. On May 17 there were only occasional patche of snow in the burned stand, whereas the unburned control still had a nearly continuous cover 13 cm in depth. The burned stand was free of snow about 7 days before the unburned control was. The effect that this had on plant growth was dramatically shown in the lower, heavily burned stand, where clumps of sedge tussoc (*Eriophorum vaginatum* L.) were in full flower on May 17 while th was still a nearly continuous snow cover in the adjacent unburne control.

Snow came early in the fall of 1972. The first snow fell on September 20 and remained on the ground for the rest of the seas This gave a snowfree period of 126 days for the burned stands ar 119 days for the unburned controls.

Air Temperature[10]

Air temperatures were recorded with a thermograph in a standard weather bureau shelter in both the heavily burned stand and the unburned control in plot set 3 (table 2). Figure 12 illustrates the average daily air temperature within these stands. There were no significant differences in the shelter temperature between the two stands. The temperatures during this period showed a typical pattern for interior Alaska: occasional intensive cold periods in December, January, and February; and a general warming trend through March, April, and May, with the average daily temperature rising above 0°C at the end of April. The warmest period of the summer was in mid-June, followed by generally lower temperatures in July and August. The daily mean temperature crossed below the freezing point for the first time in mid-September but was above it in an exceptionally warm period in mid-October.

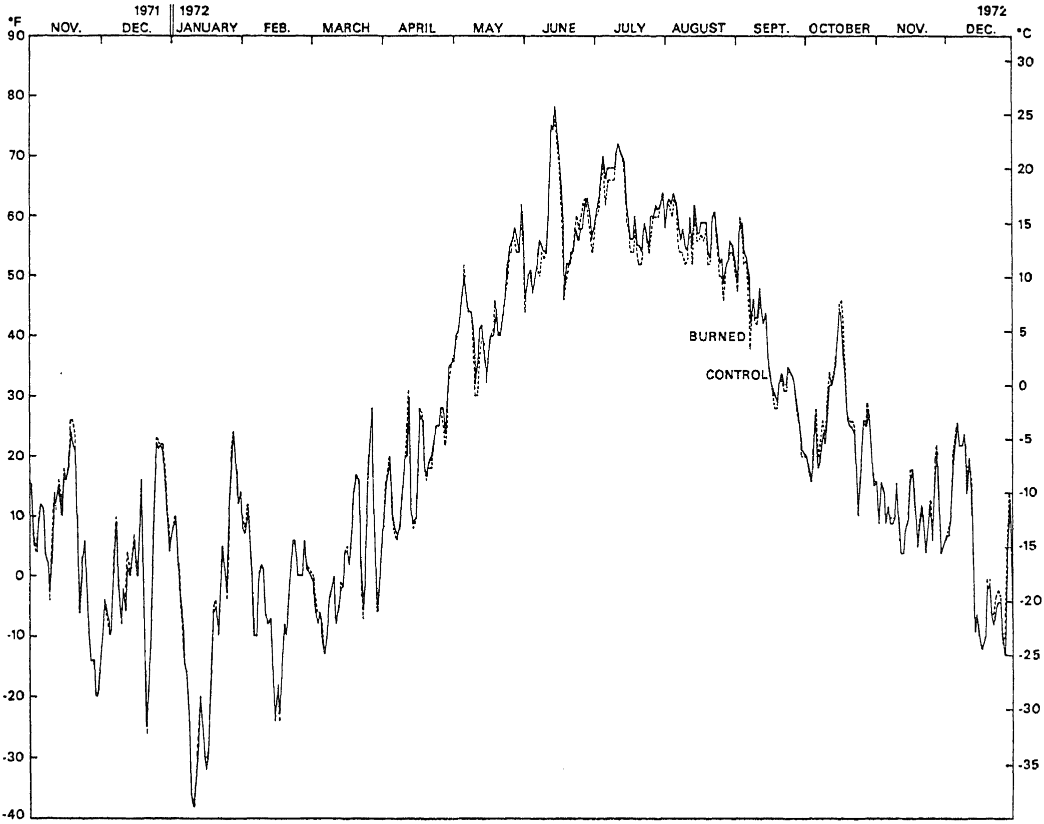

Figure 12.--Average daily air temperature in a burned black spruce stand and an adjacent unburned control.

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[10] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and A. E. Helmers, Research Hydrologist (retired), USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Table 6 provides a monthly summary of the air temperatures from November 1971 to December 1972. In 1972, the average daily temperature was -3.55°C for the burned stand and -3.44°C for the unburned control. This compares with -4.5°C at the Fairbanks International Airport for the same period and -3.5°C for the 30-year average. From these 1971-72 records it appears that the Wickersham Dome area is slightly cooler than Fairbanks in the summer and slightly warmer during the extreme cold periods in winter. This pattern has held in subsequent years. The summaries for 1973 and 1974 are not included in this report but are on file at the Institute of Northern Forestry, Fairbanks.

Table 6--Average air temperatures (°C) in a heavily burned stand and an adjacent unburned control (plot set 3), November 1971 to December 1972

Year and month	Burned stand			Unburned control		
	Average	Maximum	Minimum	Average	Maximum	Minimum
1971:						
November	-14	-11	-17	-15	-12	-18
December	-16	-13	-20	-16	-13	-20
1972:						
January	-22	-19	-25	-22	-19	-25
February	-20	-16	-23	-20	-17	-23
March	-16	-11	-22	-17	-11	-23
April	-8	-2	-13	-8	-2	-13
May	7	12	2	8	13	2
June	14	20	8	14	21	8
July	16	22	11	17	23	11
August	13	17	9	14	19	9
September	4	8	-1	4	8	-1
October	-4	-1	-6	-4	-1	-7
November	-12	-8	-15	-12	-9	-15
December	-15	-12	-18	-16	-13	-18

Average daily temperature for 1972:
Burned stand -3.55
Unburned control -3.44

Stream Water Quality[11]

Since most of the burned area drains into Washington Creek, a limited sampling program was initiated on this stream in an attempt to determine the effects of the fire on water quality. F. B. Lotspeich, of the Environmental Protection Agency's Arctic Environmental Research Laboratory, established four water sampling stations on Washington Creek (two below the burned area and two above it) and obtained samples the day the fire was controlled and 1 and 2 weeks after it was controlled. These samples of stream water were analyzed in the laboratory to determine whether the chemical retardants dropped had enriched the water and how much sedimentation resulted from erosion of the firelines. Results were summarized by Lotspeich (1972).

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[11] This section was prepared by F. B. Lotspeich, Soil Scientist, Special Studies Branch, U.S. Environmental Protection Agency, Corvallis, Oregon; and C. T. Dyrness, Supervisory Soil Scientist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Although measurements of suspended sediment were not obtained for the first set of water samples, the sediment content of Washington Creek below the burned area was estimated to be about 300-500 mg/liter at the time the fire was controlled. The primary source of sediment was thought to be erosion of firelines caused by thawing of the permafrost. Therefore, immediately after the fire, the Bureau of Land Management constructed water bars across firelines in an effort to curtail this form of erosion. These measures were apparently successful; water samples collected several days later were uniformly low in suspended sediment content--the maximum value, 19 mg/liter. Just prior to the third and last sampling (about 2 weeks after control of the fire), sufficient rain fell to cause Washington Creek to rise. Apparently some sediment was still entering the drainage from the bulldozed firelines because at this time maximum sediment content was 97 mg/liter.

Little effect of the chemical retardant could be detected in the water samples. Nitrogen content of samples collected above and below the burned area were about the same. Although amounts of total phosphate in samples collected below the fire were somewhat higher than those in control samples, amounts never exceeded the content recommended for aquatic life in "Water Quality Criteria" (Report of the National Technical Advisory Committee, Federal Water Pollution Control Administration, 1968, p. 27-110).

BIOTIC FACTORS

Vegetation Analysis[12]

One of the main objectives of the Wickersham Dome study was to follow the development of vegetation after the fire. To accomplish this, we followed vegetation trends in all 11 sample stands selected for study in 1971 and 1972 (table 2)--nine stands are in the black spruce type and 2 in aspen.

In each sample stand, 20 permanent plots were located at intervals of 30 m, usually in four rows of 5 plots. Vegetation analysis was slightly modified from a method described by Ohman and Ream (1971). At each location, the cover of ground vegetation, herbs, and low shrubs was determined in a 1-m^2 plot. Tall shrubs were counted and diameters measured in a 4-m^2 plot. Tree seedlings--trees less than 1.3-m in height--were also recorded on the 4-m^2 plot.

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[12] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Density and basal area of trees and saplings were determined by the point-quarter method. Saplings were defined as trees reaching a height of 1.3 m (b.h.) but having a diameter of less than 2.54 cm.

Computer programs were used to summarize the information. Values of percent frequency, cover, relative frequency, relative cover, and importance were determined for the ground cover, herbs, and low shrubs. Frequency, number of stems per hectare, basal area, relative frequency, relative density, and relative dominance were determined for trees and tall shrubs. These values were determined for all species in each stand.

In addition, data for the four heavily burned stands and the two lightly burned stands were summarized and compared with the summary of all four unburned stands for each year. Finally, data from all stands for each year were run through a clustering program by the agglomerative method (Orloci 1967).

The vegetation changes in selected stands the first 3 years after the fire are shown in tables 7, 8, and 9. In each case the vegetation data for the burned stand are compared with the paired unburned control.

1.--BS-3H and BS-3C are heavily burned and unburned black spruce stands in plot set 3 (table 2).

The outstanding feature of stand BS-3H is the rapid development of the herbaceous cover--from 1 percent during the summer of the fire (1971) to 21 percent by 1974 (table 7 and fig. 13). In contrast, the unburned control had only 3.5-percent herbaceous cover. The moss and liverwort cover returned, mainly because of three species--*Polytrichum juniperinum* Hedw., *Marchantia polymorpha* L., and *Ceratodon purpureus* (Hedw.) Brid., but the return was slow. The moss and lichen species which made up 80 percent of the cover in the unburned control had not returned at the end of 3 years.

Recovery of *Salix scouleriana* has been rapid; density reached a peak of 15,250 stems per hectare in 1973 and declined somewhat in 1974, but the basal area continues to increase. By 1973 the basal area of the willow was equal to that in the unburned control and by 1974 it was nearly three times as large. *Rosa acicularis* was also more abundant in the burn than in the control.

Few species invaded the stand during the 3 years after the fire. Most development was from plant parts that remained alive after the fire. Even fireweed (*Epilobium angustifolium* L.) was present in the control; in the burned stand it developed first from subsurface rhizomes. Later spread has been by both rhizome and seed. Two exceptions to this are the liverwort and moss, *Marchantia polymorpha* and *Ceratodon purpureus*; neither was recorded in the unburned control, but both have spread rapidly in the burned area, primarily on areas of exposed mineral soil.

Table 7--Analysis of vegetation in a heavily burned ridgetop black spruce stand (BS-3H) and an adjacent unburned control stand (BS-3C) in black spruce for 4 years after a 1971 wildfire[1]

Species	Density					Basal area (m^2/ha) or frequency (percent)				
	1971	1972	1973	1974	Control	1971	1972	1973	1974	Control
	- - -Number of stems per hectare- - -					- -Square meters per hectare- -				
Trees:										
Picea mariana--										
Live trees	0	0	0	0	2,292	0	0	0	0	6.883
Dead trees	1,320	1,179	1,511	1,568	0	0	0	0	0	
Saplings	0	0	0	0	2,024	0	0	0	0	
						- - - -Frequency (percent)- - - -				
Seedlings and layerings	0	250	375	2,750	13,250	0	5	5	20	90
Populus tremuloides--										
Seedlings	0	0	125	0	0			5		
						- -Square meters per hectare- -				
Tall shrubs:										
Salix scouleriana	2,375	8,625	15,250	9,875	2,500	0.05	0.175	0.55	1.7	0.6
Rosa acicularis	1,250	1,625	1,750	2,375	375	.025	.03	.04	.05	.01
Alnus crispa	250	5,000	3,375	3,875	0	0	.088	.06	.21	0
Salix sp.	0	250	0	125	0	0	0	0	--	0
Rubus idaeus	0	0	250	0	0	0	0	--	0	0
Total tall shrubs	3,875	15,375	20,625	16,250	2,875	.075	.30	.66	1.96	.61
	- - - - - -Cover (percent)- - - - - -					- - - -Frequency (percent)- - - -				
Low shrubs:										
Ledum groenlandicum	0.6	1.2	2.10	3.70	4.60	60	70	55	50	80
Vaccinium uliginosum	0	2.7	3.95	5.15	9.45	0	90	70	80	95
Spiraea beauverdiana	0	.25	.05	.25	0	0	25	5	15	0
Vaccinium vitis-idaea	0	.15	.20	.35	6.90	0	15	15	35	100
Ledum decumbens	0	.05	0	0	0	0	5	0	0	0
Chamaedaphne calyculata	0	.05	0	0	0	0	5	0	0	0
Empetrum nigrum	0	0	0	0	.20	0	0	0	0	10
Oxycoccus microcarpus	0	0	0	0	.05	0	0	0	0	5
Total low shrubs	.60	4.40	6.30	9.45	21.20					
Herbs:										
Calamagrostis canadensis	0.80	1.90	2.8	7.50	0.20	75	85	85	75	20
Rubus chamaemorus	.15	.10	.10	.20	0	15	10	10	10	0
Equisetum sylvaticum	.10	1.5	1.35	7.15	.05	10	55	40	60	5
Cornus canadensis	.10	.35	.35	1.80	.35	10	35	25	35	35
Geocaulon lividum	.05	.10	.25	.05	2.60	5	10	15	5	90
Polygonum alaskanum	0	.05	0	0	0	0	5	0	0	0
Mertensia paniculata	0	.05	0	0	0	0	5	0	0	0
Epilobium angustifolium	0	.05	2.95	4.05	.05	0	5	25	55	5
Lycopodium complanatum	0	0	0	0	1.40	0	0	0	0	20
Equisetum arvense	0	0	0	.15	0	0	0	0	10	0
Lycopodium clavatum	0	0	0	0	.80	0	0	0	0	35
Total herbs	1.20	4.10	7.8	20.9	3.51					
Mosses and lichens:										
Polytrichum juniperinum	0	.40	.65	5.10	1.70	0	40	65	45	65
Other mosses	0	.10	0	.10		0	5	0	5	0
Marchantia polymorpha	0	.05	.10	.10		0	5	5	5	0
Ceratodon purpureus	0	0	1.00	1.70		0	0	20	40	0
Dicranum sp.	0	0	.05	0		0	0	5	0	0
Pleurozium schreberi	0	0	0	0	56.25	0	0	0	0	90
Cladonia rangiferina	0	0	0	0	6.05	0	0	0	0	95
Nephroma arcticum	0	0	0	0	6.45	0	0	0	0	35
Aulacomnium palustris	0	0	0	0	2.40	0	0	0	0	60
Peltigera aphthosa	0	0	0	0	2.00	0	0	0	0	50
Cladonia spp.	0	0	0	0	1.20	0	0	0	0	40
Peltigera canina	0	0	0	0	1.80	0	0	0	0	25
Fungi	0	0	0	0	.60	0	0	0	0	55
Cetraria islandica	0	0	0	0	.60	0	0	0	0	20
Hylocomium splendens	0	0	0	0	.50	0	0	0	0	20
Parmelia sp.	0	0	0	0	.25	0	0	0	0	25
Cetraria sp.	0	0	0	0	.10	0	0	0	0	10
Mnium sp.	0	0	0	0	.20	0	0	0	0	5
Total mosses	0	.55	1.80	7.00	61.05					
Total lichens	0	0	0	0	18.45					
Total mosses and lichens	0	.55	1.80	7.00	80.10					
Total ground cover	1.80	9.05	14.90	37.35	104.81					

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[1] -- = negligible

Table 8--Analysis of vegetation in a heavily burned stand (AS-1B) and an adjacent unburned control stand (AS-1C) in aspen for 1972, 1973, and 1974 after a 1971 wildfire

Species	Density				Basal area (m^2/ha) or frequency (percent)			
	1972	1973	1974	Control	1972	1973	1974	Control
	- -Number of stems per hectare- -				Square meters per hectare			
Trees:								
Populus tremuloides--								
Live trees	0	0	0	1,323	0	0	0	20.080
Dead trees	843	847	851	465	0	0	0	
Saplings	0	6,514	27,208	13	0	0	0	
Root suckers	198,375	130,000	8,125	3,875	0	0	0	
Picea glauca--								
Seedlings	0	0	0	2,625	0	0	0	
Picea mariana--								
Live trees	0	0	0	518	0	0	0	1.784
Dead trees	371	397	543	135	0	0	0	
Saplings	0	0	0	578	0	0	0	
Seedlings	0	0	0	1,125	0	0	0	
Betula papyrifera--								
Live trees	0	0	0	233	0	0	0	2.621
Dead trees	134	138	54	76	0	0	0	
Saplings	0	0	0	66	0	0	0	
Seedlings	0	0	0	250	0	0	0	
Tall shrubs:								
Rosa acicularis	4,625	6,000	9,125	1,875	.09	.11	.18	.04
Alnus crispa	500	750	250	5,000	.01	.01	0	1.68
Total tall shrubs	5,125	6,750	9,375	6,750	.10	.12	.18	1.72
	- - - -Cover (percent)- - - -				- -Frequency (percent)- -			
Low shrubs:								
Ribes triste	.05	0	.65	--	5	0	35	
Vaccinium vitis-idaea	0	0	0	5.10	0	0	0	75
Vaccinium uliginosum	0	0	0	2.15	0	0	0	40
Linnaea borealis	0	0	0	2.75	0	0	0	10
Ledum groenlandicum	0	0	0	.65	0	0	0	25
Total low shrubs	.05	0	.65	10.65				
Herbs:								
Corydalis sempivirens	1.15	.05	.05	0	10	5	5	0
Epilobium angustifolium	.45	4.9	12.0	.25	20	90	90	20
Calamagrostis canadensis	.20	.50	6.8	1.45	20	30	50	80
Cornus canadensis	.15	.65	1.5	4.95	15	30	40	100
Pyrola secunda	0	.05	0	0	0	5	0	0
Stellaria sp.	0	0	.1	0	0	0	10	0
Geocaulon lividum	0	0	0	.65	0	0	0	20
Lycopodium sp.	0	0	0	.50	0	0	0	10
Total herbs	2.35	6.2	20.55	7.8				
Mosses and lichens:								
Marchantia polymorpha	.25	6.6	6.9	0	15	40	45	0
Liverwort	.15	0	0	0	10	0	0	0
Polytrichum juniperinum	.05	.05	1.40	.20	5	5	65	10
Fungi	.05	.35	.65	.35	5	35	65	30
Ceratadon purpureus	0	20.9	31.3	0	0	100	80	0
Ptilium ciliare	0	.15	0	.35	0	10	0	10
Other mosses	.75	2.00	0	0	45	5	0	0
Parmelia sp.	0	.10	0	1.25	5	0	0	70
Drepanocladus sp.	0	0	0	3.45	0	0	0	75
Pleurozium schreberi	0	0	0	4.20	0	0	0	25
Hylocomium splendens	0	0	0	1.15	0	0	0	45
Cetraria sp.	0	0	0	.30	0	0	0	30
Peltigera aphthosa	0	0	0	.50	0	0	0	5
Aulacomnium palustris	0	0	0	.10	0	0	0	10
Cladonia sp.	0	0	0	.10	0	0	0	10
Total mosses and lichens	1.25	30.2	40.36	12.55				
Total ground cover	3.65	36.40	61.50	31.00				

Establishment of spruce seedlings has been low in this stand; only 20 percent of the 4-m^2 plots contained any seedlings, and the total was only 2,750 per hectare in 1974. The dead black spruce remained standing, so there was significant decrease in density.

2.--BS-2H, BS-2L, and BS-2C are heavily burned, lightly burned, and unburned black spruce stands in plot set 2 (table 2). These three stands are representative of a black spruce stand underlain by permafrost and with a thick organic layer. Table 8 summarizes the analysis of vegetation for the three stands.

Development of vegetation in the heavily burned stand was similar to that described for stand BS-3H; i.e., slow development of the low shrubs and herbaceous layer. The moss layer developed slowly, and total cover reached 11 percent in 1974--primarily a result of the development of *Ceratodon purpureus*. Density of dead trees did not decrease appreciably after the summer of the fire. Tree seedlings became numerous, approximately 21,000 per hectare in 1974. Resprouting of shrubs was slow; the total number of tall shrubs in the heavily burned stand in 1974 was only a third that of the unburned control.

The lightly burned stand developed in a different manner than the heavily burned stand (fig. 14). A number of trees and saplings survived the fire, but these died during the 3 years after the fire so that only 61 per hectare remained alive at the end of the 1974 season. Because of the presence of extensive area of unburned or partially burned mosses, spruce seedlings germinated in large numbers; nearly 40,000 per hectare were recorded in 1974.

After the fire, nearly 40 percent of the ground cover was still alive in the lightly burned stand. This residual vegetation developed rather rapidly, especially in the summer of 1974, so that there was 70-percent cover by August 1974. Unlike the heavily burned stand, many moss and lichen species of the original stand persisted after the fire, and the cover slowly increased. In addition, the moss cover has been augmented by the growth and spread of *Ceratodon purpurea*. All the *Cladonia* species of lichens survived the light burn, whereas none survived the heavy burn. It appears that the lightly burned stand will return to its original condition much more rapidly than the heavily burned stand.

3.--AS-1B and AS-1C are a heavily burned stand and an unburned control in aspen in plot set 4 (table 2).

The heavily burned stand showed a very rapid revegetation rate, especially in the development of root suckers (table 8). The 1st year after the fire (1972), there were nearly 200,000 aspen shoots per hectare; this dropped to 130,000 in 1973 and to 8,125 per table 8 in 1974. Several other tree species present before the burn--black spruce, white spruce, and paper birch--have not developed seedlings since the fire.

The number of tall shrubs increased rapidly because *Rosa acicularis* spread from stem and root shoots. The low shrubs, although having an 11-percent cover in the unburned control, had less than 1-percent cover 2 years after the fire.

Table 9--Analysis of vegetation in heavily burned (BS-2H) and lightly control stand (BS-2C) in lower slope black spruce

Species	Density								
	Heavy burn				Light burn				
	1971	1972	1973	1974	1971	1972	1973	1974	Control
	-Number of stems per hectare-								
Trees:									
Picea mariana--									
Live trees	0	0	0	0	697	65	64	61	1,803
Dead trees	4,431	4,739	4,149	4,089	362	1,075	1,161	2,161	0
Live saplings	0	0	0	0	1,896	62	62	62	2,593
Seedlings	0	19,750	17,750	21,375	4,375	28,250	32,125	38,875	23,250
Tall shrubs:									
Salix pulchra	125	1,500	125	1,375	500	2,250	1,250	2,125	3,125
Betula glandulosa	125	1,625	750	1,625	1,125	4,500	1,750	3,375	10,750
Rosa acicularis	0	625	125	375	0	0	0	0	0
Total tall shrubs	250	3,750	1,000	3,375	1,625	6,750	3,000	5,500	13,875
	-Cover (percent)-								
Low shrubs:									
Vaccinium uliginosum	0.10	1.00	0.70	0.70	2.50	3.80	3.05	5.10	13.85
Ledum groenlandicum	.10	1.15	1.40	2.10	2.15	2.65	1.35	4.15	6.55
Vaccinium vitis-idaea	.05	.50	.30	.90	3.45	3.55	1.65	6.10	20.35
Spiraea beauverdiana	0	.20	0	.10	0	0	0	0	0
Ledum decumbens	0	0	.05	.15	1.45	1.05	1.90	1.30	3.10
Oxycoccus microcarpus	0	0	0	0	3.80	3.90	.75	1.75	2.20
Empetrum nigrum	0	0	0	0	1.40	1.10	.90	1.25	1.90
Total low shrubs	.25	2.85	2.45	3.95	14.75	16.05	11.15	19.65	47.95
Herbs:									
Calamagrostis canadensis	.65	1.35	2.15	4.40	.70	1.50	1.45	5.15	2.20
Rubus chamaemorus	.45	1.0	1.35	2.45	1.90	3.65	2.80	7.35	7.10
Petasites frigidus	.10	.40	.15	.25	.20	.45	.10	.80	.70
Equisetum sylvaticum	0	3.35	3.60	8.95	.10	2.65	2.60	5.70	1.25
Cornus canadensis	0	.10	.15	.20	0	0	0	0	0
Epilobium angustifolium	0	.05	.10	.45	0	0	.55	.10	0
Equisetum arvense	0	0	0	.95	0	0	0	0	0
Equisetum scirpoidea	0	0	0	0	0	0	0	0	1.10
Eriophorum vaginatum	0	0	0	0	.10	.20	.60	0	.05
Pyrola secunda	0	0	0	0	0	0	0	0	.05
Unknown herb	0	0	0	0	.05	.05	0	0	0
Pedicularis labradorica	0	0	0	0	0	0	0	.25	0
Total herbs	1.20	6.25	7.55	17.65	3.05	8.50	7.50	19.95	12.45
Mosses and lichens:									
Polytrichum sp.	.05	1.00	2.80	2.05	1.40	1.70	1.55	5.30	3.65
Fungi	0	.15	.15	.05	0	.25	.10	.35	.95
Marchantia polymorpha	0	.10	.10	.35	0	0	0	0	0
Other mosses	0	.10		.10	.65	0	0	.10	1.85
Ceratadon purpureus	0	0	2.40	8.05	0	0	.10	1.75	.20
Sphagnum spp.	0	0	.05	0	11.65	12.20	7.30	13.50	36.00
Ptilium crista-castrensis	0	0	0	.05	0	0	.50	0	0
Peltigera spp.	0	0	0	.05	0	0	0	0	0
Aulacomnium palustris	0	0	0	.05	.05	1.65	3.75	2.85	14.65
Pleurozium schreberi	0	0	0	0	3.70	5.25	7.45	2.05	27.00
Hylocomium splendens	0	0	0	0	.05	0	0	1.75	4.70
Peltigera canina	0	0	0	0	0	.25	0	.65	3.40
Nephroma arcticum	0	0	0	0	0	.10	0	.10	3.10
Cladonia sylvatica	0	0	0	0	0	.10	0	.20	2.60
Peltigera aphthosa	0	0	0	0	0	.80	0	0	1.95
Cladonia spp.	0	0	0	0	.05	.30	.25	.50	2.05
Dicranum sp.	0	0	0	0	0	.10	0	.05	1.05
Cetraria spp.	0	0	0	0	.15	.20	.15	0	.95
Parmelia spp.	0	0	0	0	.10	.25	.05	.10	.85
Cladonia amaurocraea	0	0	0	0	0	.95	.35	0	.40
Cladonia rangiferina	0	0	0	0	0	.35	.05	.25	.05
Aulacomnium turgidum	0	0	0	0	0	0	0	0	.20
Cetraria islandica	0	0	0	0	0	0	0	0	.40
Unknown foliose lichen	0	0	0	0	0	0	0	0	0
Cetraria pinastre	0	0	0	0	0	0	0	0	.10
Other liverworts	0	0	0	0	0	0	0	0	.05
Total mosses and lichens	.05	1.35	5.50	10.75	19.95	23.60	21.45	30.45	106.05
Total ground cover	1.45	10.45	15.50	32.35	37.75	48.15	40.10	70.05	166.45

for 4 years after a 1971 wildfire

Basal area (m²/ha) or frequency (percent)								
Heavy burn				Light burn				
1971	1972	1973	1974	1971	1972	1973	1974	Control
-Square meters per hectare-								
0	0	0	0	0.2067	0.3424	0.1388	0.1388	2.804
0	0	0	0	0	0	0	0	0
0	0	0	0	0	.0104	.0108	.0108	.6957
-Frequency-								
0	80	100	90	30	95	95	100	100
-Square meters per hectare-								
0	0.025	0	0.05	0.0125	0.0500	0.0250	0.0375	0.07
0	0	0	.0375	.0250	.0875	.0375	.0625	.05
0	.0125	0	.0125	0	0	0	0	0
0	0	0	.1	.0375	.1374	.0625	.1125	.12
-Frequency-								
10	85	40	35	70	95	75	85	100
10	90	70	65	45	90	80	90	90
5	35	30	40	50	90	80	95	95
0	20	0	10	0	0	0	0	0
0	0	5	10	25	35	65	40	65
0	0	0	0	45	50	25	35	45
0	0	0	0	20	25	10	20	30
65	80	80	85	40	65	70	70	80
40	65	60	60	80	95	40	85	85
10	20	15	20	10	25	5	25	45
0	80	80	90	10	95	95	85	60
0	10	15	10	0	0	0	0	0
0	5	5	10	0	0	10	5	0
0	0	0	15	0	0	0	0	0
0	0	0	0	0	0	0	0	20
0	0	0	0	10	10	10	0	5
0	0	0	0	0	0	0	0	5
0	0	0	0	5	5	0	0	0
0	0	0	0	0	0	0	5	0
5	75	85	75	45	95	80	100	75
0	15	15	5	0	25	10	35	95
0	10	5	15	0	0	0	0	0
0	5	0	5	20	0	0	10	15
0	0	55	60	0	0	10	45	5
0	0	5	0	65	50	35	55	70
0	0	0	5	0	0	5	0	0
0	0	0	5	0	0	0	0	0
0	0	0	5	5	15	15	20	80
0	0	0	0	50	40	30	40	80
0	0	0	0	5	0	0	15	45
0	0	0	0	0	10	0	30	65
0	0	0	0	0	5	0	5	25
0	0	0	0	0	5	0	10	55
0	0	0	0	0	10	0	0	45
0	0	0	0	5	15	5	20	80
0	0	0	0	0	5	0	5	25
0	0	0	0	15	20	15	0	95
0	0	0	0	10	25	5	10	85
.75	0	0	0	20	5	0	15	40
.15	0	0	0	20	5	10	5	5
.15	0	0	0	0	0	0	5	5
.05	0	0	0	0	0	0	10	5
0	0	0	35	0	0	0	0	0
0	0	0	0	0	0	0	10	0
0	0	0	0	0	0	0	5	0

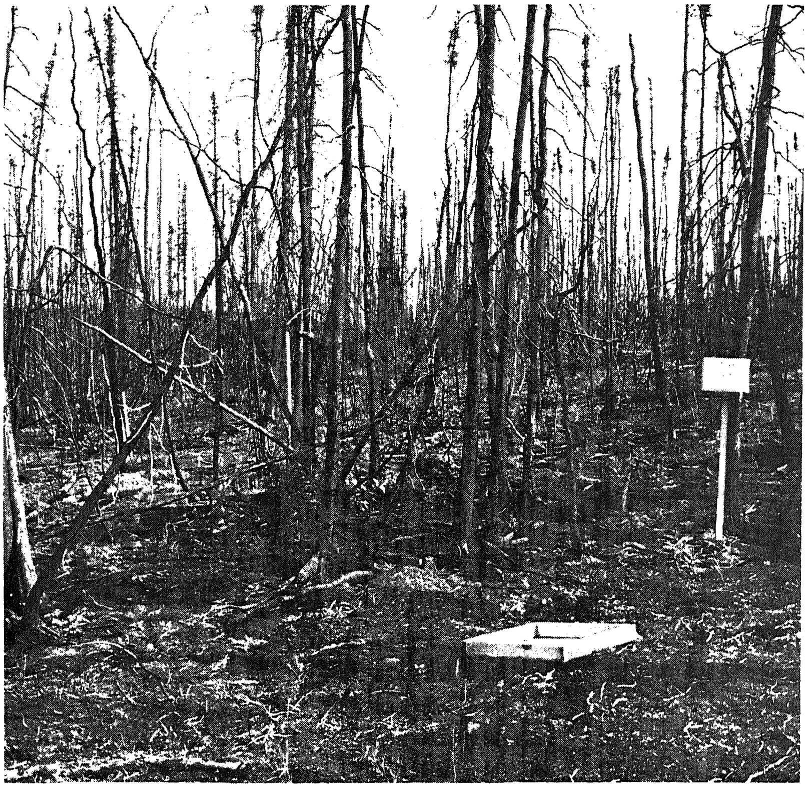

Figure 13.--Heavily burned black spruce stand (BS-3H) 1 year after the fire (August 1972) shows some development of Epilobium angustifolium *L. and* Calamagrostis canadensis.

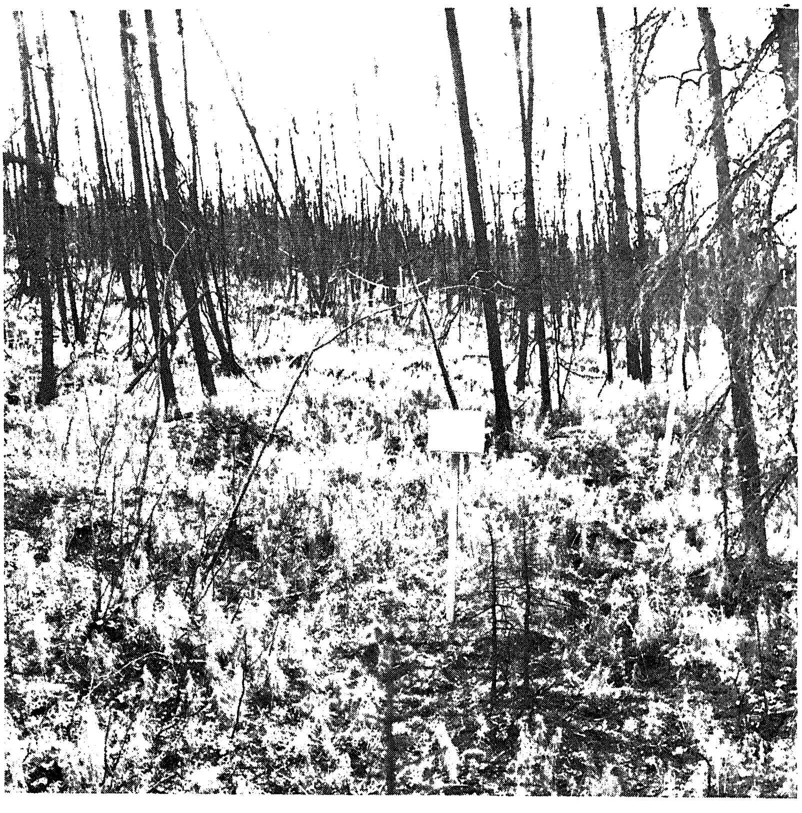

Figure 14.--Lightly burned black spruce stand 1 year after the fire (August 1972) shows the very conspicuous development of Equisetum sylvaticum.

In contrast, both the herbaceous layer and the moss and lichen cover increased rapidly until, in 1974, they occupied three times the area in the burned stand that they did in the unburned control. It is to be expected that, as the density of the canopy increases and leaf litter accumulates, the cover of mosses will be reduced.

The results of the cluster analysis for the 11 stands for the first 2 years after the fire are shown in figure 15. For purposes of this analysis, a stand was considered new each time it was resampled. At the highest level of within-group dispersion all

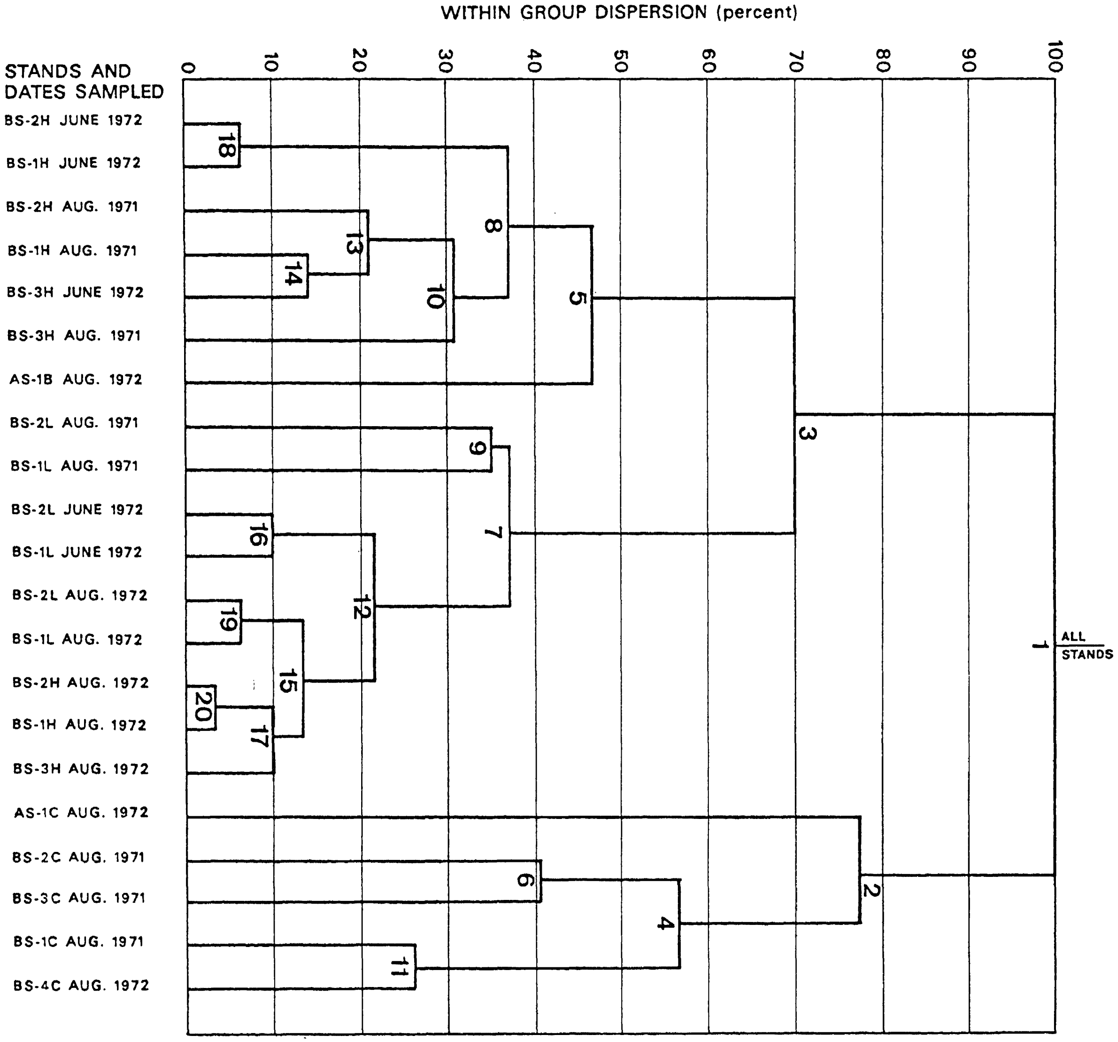

Figure 15.--Results of analysis of clusters of vegetation data (based on twenty 1-m^2 plots) collected in 11 sample stands over a 2-year period after the 1971 Wickersham Dome fire. For the within-group dispersion, a stand was treated as a new stand each time it was sampled. Burned stands were sampled in August 1971, June 1972, and August 1972; unburned controls were sampled only once.

stands were combined into one group. At the next level the stan were separated into two groups which contained all the burned stands in one group and all the unburned control stands in the other (fig. 15, group 2 and 3). Within the control group, the aspen stand is different from all the black spruce stands (group Within the black spruce types, the most similar are two stands o the west-facing slope, one at midslope and the other at the base of the slope. The ridgetop stand (BS-3H) was most similar to th east-facing stand (BS-2H) on the lower slope.

The two lightly burned stands (BS-1L and BS-2L) are more simi to each other at each analysis time than they are to themselves different sampling times (fig. 15). Also, there is a tendency f the stands to become more similar to each other as time passes. Thus, in August 1971 the within-group dispersion between the two lightly burned stands was 34 percent; in June 1972 it was 10 per and in August, 5 percent. The same tendency holds true for the heavily burned stands in the bottom of the valley (BS-1H and BS- In August 1971 the within-group dispersion for these two stands was 31 percent; in June 1972 it was 7 percent and in August, onl 3 percent.

At the last sampling of the heavily burned stands in August 1972, these stands were grouped with the lightly burned stands rather than with the heavily burned stands from the two earlier inventories.

This tendency for the stands to become more similar as time progresses indicates that the effects of the differences in inte sity of burn rapidly become less as the stands develop mature vegetation. We will follow this trend over the next few years.

Biomass[13]

Plant biomass, obtained on a unit area basis, is often a bett indication of amounts and proportions of plant species than are some other measurements, such as basal area, density, or cover. Also, it is essential to know the actual amounts of biomass--usu in units of grams per square meter, kilograms per hectare, or me tons per hectare--as inputs for studies of ecosystem processes, such as primary productivity, decomposition, or simply the flow of any nutrient through the system.

In our fire succession studies, we are interested in biomass for several reasons. Increased primary productivity has always been assumed to be one result of fire in the taiga. According t this hypothesis, a release of nutrients held in the organic laye and an increase in soil temperature result in increased activity of soil organisms and assimilation of nutrients by plant roots.

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[13] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbank Alaska.

One way to investigate productivity in successional stands is to record the biomass each year and then determine the amount of increase or decrease in each category. Coupled with this, the amount of biomass discarded by the plants each year--i.e., the litter fall--should also be determined.

At the Wickersham Dome fire study site, we established a minimum program of collection of the aboveground biomass. In 1972, biomass was determined for only one stand, the heavily burned black spruce stand on the ridgetop (BS-3H). In 1973, sampling was expanded to two more heavily burned black spruce stands (BS-1H and BS-2H) in the Cushman Creek Valley and a heavily burned aspen stand (AS-1B). In addition, the unburned control on the ridgetop (BS-3C) was sampled. Ten 1-m^2 plots were systematically located adjacent to the 20 permanent vegetation plots. All herbaceous plants, low shrubs, mosses, and lichens were clipped at ground level. The material was separated by species, ovendried, and weighed. Because of the scattered and clumped nature of the developing vegetation after the fire, the use of 10 plots resulted in low frequencies for many species and an unreliable statistical sampling. Investigations in future studies should use more, smaller plots.

For the large shrub species on the ridgetop plots (BS-3H and BS-3C), a different method was used; 50 stems were collected adjacent to the plot and an average dry weight of stems and leaves was obtained. This was then multiplied by the number of shrubs per hectare, as determined by sampling the vegetation plots, to give the weight per hectare.

Detailed biomass figures for two sets of stands are given in tables 10 and 11 and figure 16. Table 10 compares the heavily burned black spruce stand, BS-3H, for the first 3 years after the fire with comparable figures for the unburned control. Only low shrubs, herbs, grasses, mosses, and lichens are shown. In addition to the biomass in grams per square meter, the frequency in percent for each species in the 10 plots is given.

There was a slow but steady increase in the total biomass of vegetation developing after the 1971 fire. At first, the aboveground live biomass was zero or close to it, since the fire was hot enough to kill all the aboveground material. For the 1st year, the biomass was primarily shrubs, especially Labrador-tea and prickly rose (table 10). These shrubs sprouted from surviving rootstocks and continued to develop slowly so that by the end of the third summer, their biomass was close to that of the low shrubs in the unburned controls. The herbs and grasses, especially bluejoint (*Calamagrostis canadensis*) (Michx.) Beauv. and fireweed, developed more slowly but by the end of 1974 accounted for more than one-half of the biomass. In contrast, the herbs and grasses in the unburned control made up an almost insignificant part of the biomass. The moss and lichen mat, totally destroyed by the fire, was slow to develop. Two mosses and one liverwort (*Polytrichum juniperinum, Ceratodon purpureus,* and *Marchantia polymorpha*), considered fire species, have developed slowly. None of the mosses present before the fire, such as *Hylocomium splendens* (Hedw.) B.S.G. and *Pleurozium schreberi*, (Brid.) Mitt. were recorded in the burned stand. Likewise, no lichens were present, although they made up nearly one-third of the biomass of the unburned control.

Table 10--Biomass of low shrubs, herbs, mosses, and lichens of a heavily burned stand (BS-3H) and an unburned control in black spruce on the ridgetop, Wickersham Dome fire area, first 3 summers after the 1971 fire

Species	Frequency				Biomass			
	1972	1973	1974	Control	1972	1973	1974	Control
	- -Percent of 10-m^2 plots- -				- -Grams per square meter- -			
Ledum groenlandicum	90	80	70	80	3.3	6.6	17.5	16.4
Calamagrostis canadensis	80	80	80	0	3.0	8.5	10.7	0
Rosa acicularis	30	40	20	0	2.5	9.1	4.4	0
Vaccinium uliginosum	90	70	60	100	2.1	6.8	3.9	11.6
Polygonum alaskanum	10	0	0	0	.6	0	0	0
Equisetum sylvaticum	50	50	50	0	.6	3.9	5.4	0
Rubus chamaemorus	10	10	10	0	.2	.03	.2	0
Cornus canadensis	20	30	30	10	.1	.2	2.2	.02
Polytrichum juniperinum	60	60	40	80	.05	1.1	1.0	3.7
Vaccinium vitis-idaea	50	50	60	90	.04	.08	1.4	5.1
Epilobium angustifolium	10	40	60	0	.02	2.5	25.0	0
Spiraea beauverdiana	10	0	0	0	.01	0	0	0
Marchantia polymorpha	0	10	10	0	0	.1	.8	0
Geocaulon lividum	0	10	0	0	0	.03	0	0
Ceratodon purpureus	0	10	20	0	0	.6	1.3	0
Pleurozium schreberi	0	0	0	100	0	0	0	52.9
Nephroma arctica	0	0	0	70	0	0	0	36.9
Cladonia spp.	0	0	0	70	0	0	0	9.0
Hylocomium splendens	0	0	0	80	0	0	0	8.1
Dicranum sp.	0	0	0	60	0	0	0	3.6
Cetraria islandica	0	0	0	60	0	0	0	2.2
Peltigera aphthosa	0	0	0	20	0	0	0	2.0
Lycopodium annotinum	0	0	0	30	0	0	0	.8
Empetrum nigrum	0	0	0	40	0	0	0	.8
Aulacomnium palustre	0	0	0	10	0	0	0	.01
Drepanocladus sp.	0	0	0	10	0	0	0	.01
Other mosses	0	0	0	10	0	0	0	.2
Total low shrubs					8.2	22.6	27.4	33.9
Total herbs and grasses					4.3	15.1	43.3	.8
Total mosses					.05	1.8	3.1	68.5
Total lichens					0	0	0	50.1
Total					12.5	39.5	73.8	153.3
Annual increment					12.5	27.0	34.3	

Table 11--Biomass of Scouler willow (*Salix scouleriana*) in a heavily burned black spruce stand[1]

Plant component	1972	1973	1974
Leaves (g/stem)	5.1	14.1	20.0
Wood (g/stem)	6.2	36.8	66.4
Total (g/stem)	11.3	50.9	86.3
Stem density (number/m^2)	.8520	1.525	.9875
Leaves (g/m^2)	4.3	21.5	19.7
Wood (g/m^2)	5.3	56.2	65.5
Total (g/m^2)	9.6	77.6	85.2
Annual increase (g/m^2)	9.6	68.0	7.6

[1] Based on density of shrubs from vegetation survey and average weights of 50 stems collected adjacent to the stand.

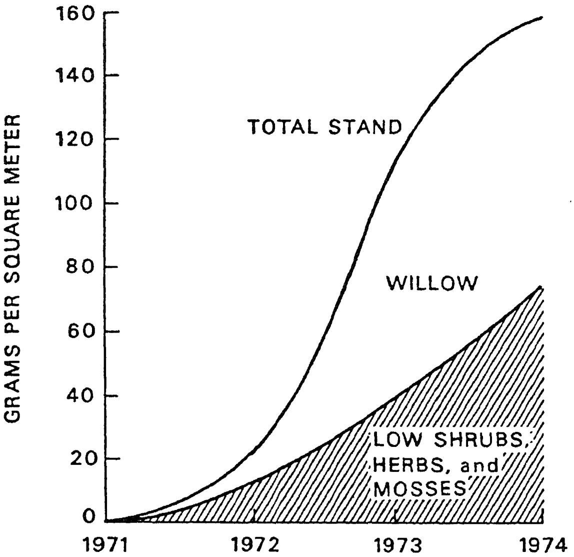

Figure 16.--Biomass of a heavily burned black spruce stand (BS-3H) for 4 years after the 1971 fire.

Table 11 shows the development of the biomass of the Scouler willow in the same stand. After the fire, the willows developed entirely from stump shoots--four to six times as many stems as had been growing previously. In spite of having been trimmed to the ground by snowshoe hares in the fall of 1971, they produced 11 g of biomass per stem in 1972. This increased, so that by the end of 1974, each stem averaged 86 g, about one-fourth of which was leaves and the rest woody material.

On an area basis, there was a rapid increase in biomass of the willows, especially between 1972 and 1973--68 g/m^2 (table 11). Between 1973 and 1974, there was a reduction in the number of stems per hectare because of overcrowding and thinning within the individual clumps. Therefore, the biomass increment slowed down (to 7.6 g/m^2). Figure 16 shows graphically the increase in biomass in this stand for the 3 years after the fire.

The development of biomass in the burned aspen stand has been large compared with that in the black spruce stand. Approximately 60 percent of the biomass in the burned aspen stand is from aspen shoots (table 12). Fire moss (*Ceratodon purpureus*) and liverwort (*Marchantia polymorpha*), however, have also developed and spread, as well as fireweed and blue joint, resulting in a large annual increment in spite of heavy cropping by moose and snowshoe hare. In the winter of 1972-73, every aspen stem was clipped at snow level; however, this heavy browsing seemed to have little effect on shoot growth the following summer and seemed to encourage the development of lateral branches. This very high production of browse on a good site illustrates the value of fire in the production of wildlife habitat.

Table 13 shows the biomass in the four heavily burned stands and gives a rough indication of the annual net increment of the and 3d summers after a June 1971 wildfire

Species	Frequency		Biomass	
	1973	1974	1973	1974
	Percent in 1-m² plots		Grams per square meter	
Ceratodon purpureus	20	100	11.8	114.5
Epilobium angustifolium	70	70	9.5	21.2
Corydalis sempervirens	20	10	.8	.06
Calamagrostis canadensis	40	40	.9	24.8
Rosa acicularis	20	0	.6	9.0
Marchantia polymorpha	20	40	.5	69.6
Cornus canadensis	30	50	.08	3.4
Polytrichum sp.	10	0	.05	0
Rubus chamaemorus	30	0	.02	0
Picea mariana	10	0	.01	0
Fungi	0	40	0	1.9
Viburnum edule	0	10	0	24.0
Total - mosses, herbs, and shrubs	90	90	24.26	268.46
Populus tremuloides:				
Leaves			96.5	102.2
Stems			357.9	434.8
Total			454.4	537.0
Total for stand			478.66	805.46
Annual increment			239.33	326.86

Table 13--Total biomass in four heavily burned stands at the Wickersham Dome fire site, 1972-74[1]

Stand	Biomass		
	1972	1973	1974
	Grams per square meter		
BS-2H:			
Standing crop	--	17	33
Annual increment	--	8.5	16
BS-3H:			
Standing crop without *Salix*	12	40	74
Annual increment without *Salix*	12	28	34
Standing crop with *Salix*[2]	22	117	159
Annual increment with *Salix*	22	95	42
BS-1H:			
Standing crop without moss	--	63	92
Annual increment without moss	--	31.5	29
Standing crop with moss[3]	--	86	118
Annual increment with moss	--	43	32
AS-1B:			
Standing crop	--	479	804
Annual increment	--	239.5	325

[1] -- = no data.

[2] Includes *Salix scouleriana* sampled by average weight and density.

[3] Includes unburned sphagnum clumps.

biomass for each stand. Increase in biomass in the three black spruce stands was extremely low compared with the more productive aspen stand. Even in the ridgetop stand (BS-3H) where the growth of *Salix scouleriana* was rapid, production was not high on an area basis because the density of the original clumps was low. Productivity in the two lowland black spruce stands was low. In stand BS-2H, 3 years after the fire, the biomass was only 33 g/m^2. This area was the most heavily burned, and neither fireweed nor *Calamagrostis* has developed extensively; growth of shrubs, primarily resin birch (*Betula glandulosa* Michx.) and Labrador-tea, has also been slow.

In stand BS-1H there were many *Sphagnum* mounds that did not burn. These have been growing slowly since the fire. For this stand, two biomass figures are given (table 13)--including the moss biomass and excluding it--since the *Sphagnum* did not develop from zero aboveground biomass as the other species have. The biomass for BS-3H is shown with and without Scouler willow because this was the only black spruce stand to develop an extensive tall shrub layer.

Litter Fall[14]

Annual litter fall, the plant material that falls to the ground each year, has been shown to be closely related to productivity in many ecosystems. Many studies of litter fall have been made throughout the world. Any study of primary productivity within an ecosystem must have information on litter fall to distinguish gross and net primary production. Knowledge of litter fall--how material moves from the living, aboveground biomass into the soil organic layers--is also essential in studies of the flow of nutrients and the process of decomposition.

At the Wickersham Dome fire area, samples of litter fall were collected in both burned and unburned stands. The objective was to determine differences in the production of litter as the vegetation develops and to compare characteristics of litter in burned stands with those in unburned stands.

Ten 1/4-m^2 litter trays were placed in each stand. The material from the trays was collected at the beginning and end of each summer season. This material was separated by species and parts and then ovendried. Final results were expressed as grams per square meter.

In June 1972, 70 trays were placed in seven black spruce stands: three heavily burned stands (BS-1H, BS-2H, and BS-3H), two lightly burned stands (BS-1L and BS-2L), and two unburned stands (BS-2C and BS-3C). In June 1973, 30 trays were set out in three other stands: a heavily burned aspen stand (AS-1B), an unburned aspen stand (AS-1C), and an unburned black spruce stand (BS-4C).

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[14] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Originally, the fall collection was to be made after the year's leaf fall. In 1972 and in 1974, however, the first snow came before leaf fall was complete, making it impossible to obtain a complete fall collection of litter. Therefore, future collections will be made only in the spring after snowmelt. All data will be summarized from June of one year to June of the next year.

Small (1/4-m^2) trays are inadequate for sampling large litter, such as branches or whole trees. To obtain some idea of the large litter in the burned stand at ridgetop stand BS-3H, we established a series of five 10-m^2 plots. All loose litter larger than 1-cm diameter was removed in June 1972. Each succeeding year the litter was collected from these plots and weighed.

A summary of the total litter fall for each stand, as well as an average for burn categories, is shown in table 14. In the unburned black spruce stands litter fall was low, amounting to approximately 10 g/m^2 per year.

Table 14--Litter fall in burned and unburned stands for 3 years after the 1971 Wickersham Dome fire

Stand	Collection period					
	June to Sept. 1972[1]	Oct. 1972 to June 1973	Year, June 1972 to June 1973	June to Sept. 1973	Oct. 1973 to June 1974	Year, June 1973 to June 1974
	Grams per square meter					
	BLACK SPRUCE					
Heavily burned:						
BS-1H	--	5.12	5.12	2.08	0.44	2.52
BS-2H	--	3.64	3.64	1.76	.08	1.84
BS-3H	8.84	3.16	12.00	3.36	2.68	6.04
Average			6.92			3.47
Lightly burned:						
BS-1L	14.40	4.48	18.88	6.48	2.20	8.68
BS-2L	--	21.04	21.04	1.08	2.24	3.32
Average			19.96			6.00
Unburned control:						
BS-2C	--	5.32	5.32	4.64	.48	5.12
BS-3C	4.60	9.40	14.00	13.80	3.24	17.04
Average			9.66			11.08
	ASPEN					
Heavily burned:						
AS-1B	[2]	--	--	108.84	8.72	117.56
Unburned control:						
AS-1C	[2]	--	--	153.40	22.96	176.36

[1] -- = negligible amount.

[2] Litter trays were not set out until June 1973.

Litter fall in the burned black spruce stands originated primarily from dead standing trees and from willows. Litter from the low shrubs and herbs was localized; stature of these plants is often too low to allow deposition in the trays. Litter fall in the lightly burned areas was heaviest the second summer after the fire; it dropped off during the 3d year. Litter fall in the heavily burned stands followed a similar pattern but was less abundant compared with that in the light burn. Most of the needles and small branches and cones were not consumed in the lightly burned stands, whereas in the heavily burned stands they either were consumed or dropped to the ground the first summer.

The rate of litter fall is expected to accelerate as the bark begins to slough off the standing dead trees and as small branches and cones fall. Eventually, as the shrubs become larger and more numerous and when the developing spruce seedlings become taller, the litter fall rate should increase to at least that of the unburned stand.

In the burned aspen stand, litter production was relatively high, 118 g/m^2 per year, because of rapid development of the aspen sucker shoots. Growth of these shoots was so rapid in 1974 that the litter in the 1974-75 collection year may nearly equal that of the unburned controls.

The large litter, 1-cm diameter and larger, was sampled in only one heavily burned black spruce stand. The original quantity of large litter in these plots when they were established in the summer of 1972 was 218 g/m^2 (range 19 to 614). A second collection in September 1973 yielded only 4.3 g/m^2 (range 1 to 8.2). Collections will be continued on a yearly basis.

Litter Decomposition[15]

To determine relative rates of litter decomposition, we established a series of litterbags in two heavily burned stands and two unburned controls in the fall of 1972. These bags were to be collected over a period of 5 years and their contents analyzed.

Three species were used for the litter. Needles were collected from black spruce growing on the site, and 20-g samples were placed in 30- by 30-cm nylon mesh bags. Leaves were collected from both bog blueberry and Labrador-tea; 5-g samples of each were placed in nylon mesh bags measuring 15 cm on each side.

The series was repeated four times at each stand. At each site eight bags for each species were stapled to a wire running along the ground. In all, 32 bags for each species were placed in each stand. Collections were made twice yearly, in spring and late fall, for the next 3 years and in the fall only for the following

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[15] This section was prepared by L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

2 years. The first collections were made in May 1973. The samples were analyzed in the laboratory and results compared with data on original weight and nutrient content.

Table 15 summarizes the weight loss of the litterbags for the first 2 years after the bags were placed in the stands. Losses of biomass for the spruce needles and Labrador-tea leaves are similar, 30-31 percent. The blueberry leaves lost slightly more weight, about 37 percent. As would be expected, the weight loss was more rapid during summer than winter. There was no appreciable difference in weight loss between the litterbags in the burned stands and those in the unburned controls.

Table 16 summarizes the nutrient content of the original sample (based on two analyses) and of the samples from May and September 1973. At the time we wrote this report, the analyses of the 1974 collections were not complete, and any conclusions about differential rates of nutrient loss between the three litter samples or between the burned stand and unburned control would be premature.

In addition to analysis of the major nutrients, the samples were analyzed for lignin, acid detergent fiber, and ash content (table 17). In general, percent of weight loss of lignin from litterbag material has been found inversely related to the initial content of lignin. Unfortunately, the original samples were not analyzed for these three substances. There was probably no significant change, however, in lignin content the first winter--August 1972 until late April 1973. Spruce needles, with a lignin content of 14-18 percent, would be expected to decompose more rapidly than blueberry leaves with a lignin content of 26-32; but weight loss data indicated that blueberry leaves decomposed more rapidly than spruce needles.

At the end of this 5-year study of litter decomposition, it will be possible to compare decomposition rates between the burned stands and the unburned controls and among the litter from the three species. It is also expected that differences in the rate of release of the various elements can be compared. The general rate of decomposition of contents of the litterbags will also be compared with the contents of the litterbags from other studies in more temperate locations.

Black Spruce Seed Fall and Seedling Establishment[16]

Black spruce cones are semiserotinus; that is, they remain on the tree and open slowly, thus dispersing seed over a period of years. Therefore, provided trees are producing seed, some seed is always present on the trees (Heinselman 1957). If the cones are not destroyed by fire, this habit makes black spruce well adapted for reseeding burned over areas. It is the only interior

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[16] This section was prepared by J. C. Zasada, Silviculturist, L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Table 15--Weight loss of litterbags for 2 years after their installation in burned stands and their unburned controls[1]

Litter	Aug. 1972	May 1973	Sept. 1973	May 1974	Sept. 1974	Weight loss after 2 years
	- - - -Grams dry weight- - - -					Percent
Picea mariana needles:						
Unburned controls	20.0	16.9	15.0	14.7	13.8	31.3
Burned stands	20.0	16.5	14.8	14.4	13.8	31.1
Ledum groenlandicum leaves:						
Unburned controls	5.0	4.3	3.9	3.9	3.5	30.3
Burned stands	5.0	4.3	3.8	3.7	3.5	30.6
Vaccinium uliginosum levels:						
Unburned controls	5.0	3.9	3.4	3.4	3.2	37.0
Burned stands	5.0	4.0	3.4	3.5	3.1	37.4

[1] Each value is an average of 8 bags.

le 16--Original (fall 1972) nutrient content of leaves and needles in litterbags from burned stands and unburned controls and the nutrient content after 1 winter and 1 summer of decomposition, Wickersham Dome fire site[1]

ient	*Vaccinium uliginosum* leaves			*Ledum groenlandicum* leaves			*Picea mariana* needles		
	August 1972	May 1973	September 1973	August 1972	May 1973	September 1973	August 1972	May 1973	September 1973
	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - -	-Percent-	- - - - - - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -
stand	0.12	0.184 ± 0.035	0.164 ± 0.018	0.10	0.109 ± 0.016	0.104 ± 0.020	0.06	0.075 ± 0.005	0.090 ± 0.037
and	.12	.105 ± .026	.105 ± .026	.10	.104 ± .012	.106 ± .005	.06	.084 ± .013	.079 ± .014
stand	.0025	.009 ± .014	.006 ± .004	.0028	.007 ± .004	.005 ± .004	.0075	.014 ± .005	.008 ± .004
and	.0025	.013 ± .007	.011 ± .006	.0028	.013 ± .008	.009 ± .004	.0075	.013 ± .008	.013 ± .004
percent):									
stand	,0915	.091 ± .021	.084 ± .015	.090	.109 ± .020	.121 ± .018	.165	.161 ± .013	.160 ± .012
and	.0915	.044 ± .009	.040 ± .016	.090	.118 ± .021	.122 ± .018	.165	.158 ± .016	.155 ± .008
nt):									
stand	.010	.017 ± .010	.026 ± .011	.015	.021 ± .009	.025 ± .007	.018	.020 ± .006	.018 ± .006
and	.010	.020 ± .006	.024 ± .007	.015	.025 ± .010	.026 ± .006	.018	.022 ± .010	.017 ± .005
rcent):									
stand	.55	.644 ± .172	.713 ± .141	.488	.696 ± .073	.737 ± .068	.900	1.186 ± .164	1.400 ± .163
and	.55	.410 ± .070	.496 ± .129	.488	.756 ± .155	.810 ± .127	.900	.948 ± .203	1.340 ± .101
percent)									
stand	.65	.253 ± .108	.119 ± .042	.30	.294 ± .084	.146 ± .046	.26	.181 ± .023	.113 ± .030
and	.65	.206 ± .102	.103 ± .060	.30	.217 ± .079	.140 ± .042	.26	.173 ± .042	.096 ± .028
(percent):									
stand	.117	.099 ± .017	.127 ± .028	.090	.087 ± .022	.097 ± .032	.055	.056 ± .011	.052 ± .022
and	.117	.107 ± .025	.112 ± .021	.090	.064 ± .026	.083 ± .027	.055	.064 ± .010	.062 ± .034
rcent):									
stand	1.644	.463 ± .033	.495 ± .063	1.298	.340 ± .042	.361 ± .020	.675	.191 ± .022	.188 ± .015
and	1.644	.561 ± .039	.595 ± .027	1.298	.360 ± .094	.354 ± .037	.675	.241 ± .055	.194 ± .027

alue is based on 8 observations. Plus or minus signs indicate standard error of the mean.

Table 17--Lignin, acid detergent fiber, and ash content of leaves and needles from burned stands and unburned controls after 1 winter and 1 summer, Wickersham Dome fire site, 1973[1]

Content	*Vaccinium uliginosum*[2]		*Ledum groenlandicum*[2]		*Picea mariana*[3]	
	May	September	May	September	May	September
	-Percent-					
Lignin:						
Unburned control	26.66 ± 3.41	34.91 ± 1.90	31.55 ± 2.70	33.33 ± 0.99	14.75 ± 2.78	17.65 ± 1.06
Burned stand	29.00 ± 1.96	34.67 ± 1.75	32.49 ± 1.86	33.05 ± 1.02	17.86 ± 2.02	19.14 ± 2.28
Acid detergent fiber:						
Unburned control	47.02 ± 3.09	59.04 ± 1.73	52.91 ± 2.59	56.82 ± 2.39	35.96 ± 2.23	40.34 ± 1.80
Burned stand	49.86 ± 4.42	60.59 ± 2.61	54.27 ± 1.45	57.28 ± 1.90	39.94 ± 2.82	42.47 ± 3.76
Ash:						
Unburned control	.91 ± .45	.83 ± .38	.48 ± .28	.45 ± .36	.68 ± .44	.79 ± .39
Burned stand	.66 ± .29	.54 ± .30	.47 ± .25	.57 ± .42	.76 ± .43	.57 ± .50

[1] Each value is based on 8 observations. Plus or minus signs indicate standard error of the mean.

[2] Leaves contained in litterbags.

[3] Needles contained in litterbags.

Alaska tree species that exhibits this characteristic. Other tree species disperse the majority of their annual crop over a period of a few weeks to several months (Zasada and Viereck 1970, Zasada 1971; Bjorkbom 1971).

The objectives of this portion of the study were to (1) compare the quantity and quality of seed dispersed by trees on sites that burned at different intensities, (2) determine the annual dispersal pattern in a burned stand and an unburned control, (3) estimate the seed-seedling ratio (tree percent), and (4) estimate the quantity and quality of seed potentially available in the cones of the residual burned and unburned trees.

We used two types of seed traps to follow seed dispersal in three burned black spruce stands and one unburned control. Five flat traps (1-m^2 sampling surface area for each trap located 15 cm above the ground surface) were placed in all stands in August 1971. Five tall traps (1-m^2 sampling surface area for each trap located 1.3 m above the ground surface) were added in February 1972.

Seeds were collected monthly from the tall traps between February 1972 and February 1973. Seeds were collected from the flat traps each month during the summer and after snowmelt in spring until early June 1974. In winter, trap samples often contained snow which was melted and strained to remove the seed and litter; seeds were separated from the litter in the laboratory. Germination tests were conducted on unstratified seeds in petri dishes at 22°C constant temperature and 18-h days. Any seed showing activity (e.g., split seed coat, radicle emergence) was considered germinated. All ungerminated seeds were cut open and classified as either filled or empty.

In August of 1971, 1972, 1973, and 1974 new black spruce seedlings were counted on twenty 1-m^2 plots in stands BS-1L, BS-1H, and BS-3H. These counts were part of the vegetation analysis, and the methods are described in that section. Using these data on seedlings and seed fall, we estimated seedling percent (seedlings/100 seeds).

So that we could determine the total amount of black spruce seed potentially available within the burn, trees were felled in November 1971 and September 1972 and all their cones removed. Seeds were removed from the cones according to methods outlined by the USDA Forest Service (1948). The total number of seeds was determined by counting seeds in four 1-g subsamples for each tree and then multiplying that number of seeds by the total weight of seed for that tree. Germination tests were conducted on four 100-seed replications from each tree.

Quantity and quality of dispersed seed[17]

Total seed fall for the 2 3/4-year period was greater in the three burned stands than in the unburned control. Because of the large within-stand variation, however, seed fall for only the light burn was significantly higher than for the control (p=0.05). During the 1st year of the study, seed fall in all burned stands was significantly higher than in the unburned control (p=0.05). From September 1972 to June 1974, the amount of seed fall in the unburned control was significantly higher than in one heavily burned stand but not significantly higher than in the other two burned stands (table 18).

Table 18--Quantity and quality of black spruce seed dispersed between September 1971 and June 1974 in 3 burned stands and an unburned control at the Wickersham Dome fire site[1]

Stand	Total seeds per square meter			Filled seeds			Real germination		
	Sept. 1971 to Sept. 1972	Sept. 1972 to June 1974	Total	Sept. 1971 to Sept. 1972	Sept. 1972 to June 1974	Total	Sept. 1971 to Sept. 1972	Sept. 1972 to June 1974	Total
	- - - - - -Number- - - - - -			- - - - - - - - - - - - - -Percent- - - - - - - - - - - - - - -					
BS-3C, unburned	85 ± 14b	132 ± 22ab	218 ± 33b	46 ± 4a	48 ± 7ab	47 ± 5a	94 ± 3a	65 ± 10ab	77 ± 5ab
BS-1L, lightly burned	386 ± 39a	120 ± 20ab	507 ± 23a	50 ± 2a	53 ± 3ab	50 ± 2a	87 ± 2a	84 ± 4a	87 ± 1a
BS-1H, heavily burned	289 ± 15a	75 ± 9b	364 ± 22ab	43 ± 3a	56 ± 2a	75 ± 2b	75 ± 2b	58 ± 4b	70 ± 2bc
BS-3H, heavily burned	319 ± 64a	142 ± 11a	461 ± 72ab	42 ± 3a	36 ± 5b	43 ± 2a	68 ± 2b	51 ± 5b	63 ± 2c

[1] Values followed by the same letters in a column did not differ significantly at the p=0.05 level; plus or minus signs indicate standard error of the mean.

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[17] This section was prepared by J. C. Zasada, Silviculturist, L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

In interpreting these data, the reader must realize that the flat seed traps were not installed until about 2 months after the fire. Thus, the amount of seed dispersed relatively soon after the fire is not known. Wilton (1963) reported that about 370 black spruce seeds per square meter (3.7 million/ha) were dispersed in a 60-day period after an August 25 fire in Newfoundland. He concluded that this was probably less than half the available seed in the stand.

Real germination (the percentage of filled seeds which actually germinated) of seed dispersed during the 1st year was greatest in the unburned control and the lightly burned stand. For the whole study, real germination in the light burn was significantly greater than in either of the heavy burns; in the unburned control it was significantly greater than in only one of the heavy burns (table 18). These data suggest that the fire may have affected germination. This is not unexpected when the burning intensity is considered. For example, the lightly burned stand was chosen partially on the basis that all of the needles were not consumed; some trees with green needles even remained after the fire. In contrast, the needles and fine branches were consumed in the heavily burned stands. This indicates that cones on the trees in the heavily burned stands were subjected to more intense heat than those in the lightly burned stand. Thus, it would be expected that seed quality might be affected in heavily burned areas.

Estimates of seed fall obtained with tall traps were different from those obtained with flat traps. For the same time period, these estimates were 450 and 320 seeds per square meter in the heavy burn for the tall and flat traps, respectively, and 147 and 85, respectively, in the unburned control. Because of variation from trap to trap, however, the estimates within each burn category were not significantly different ($p=0.05$). There are several reasons for the possible differences, and these should be considered in future studies of seed fall. First, the design of the flat trap may have allowed the wind to blow some seeds out of the traps. In fact, on windy days movement of seeds in the traps was observed. In the tall traps, on the other hand, the seeds dropped into a receptacle at the bottom of the trap and were not affected by wind after they entered the trap. A second reason is the different sequence of collection: The tall traps were collected weekly and the flat traps only monthly during the summer and in the spring after snowmelt. Thus, when snow temporarily covered the tops of the traps, the weekly removal of the snow may have resulted in fewer seed being blown away.

Annual pattern of seed dispersal[18]

Seed dispersal patterns for a 1-year period (February 1972 to February 1973) for one of the heavy burns and the unburned control ere similar. The seed fall (total and filled seeds) was much reater, however, on the heavy burn than on the unburned control fig. 17). These findings suggest that the fire did not affect he annual dispersal pattern for the year after the fire, but it pparently resulted in more cones opening (or opening more fully) nd dispersing seed during periods of normal peak dispersal in nburned stands. The main controlling mechanism for the annual ispersal pattern is probably the opening and closing of cones n response to changes in atmospheric humidity and temperature. his is known to occur in Sitka spruce (Harris 1969) and white pruce but has not been observed in black spruce.

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[18] This section was prepared by J. C. Zasada, Silviculturist, L. A. Viereck, Principal Plant Ecologist, and M. J. Foote, General Biologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Seeds on trees.--The number of seeds present in old and new ones was highly variable in the unburned control. New cones veraged almost twice as many seeds as old cones; however, old ones contained more than 26,000 seeds per tree (table 19).

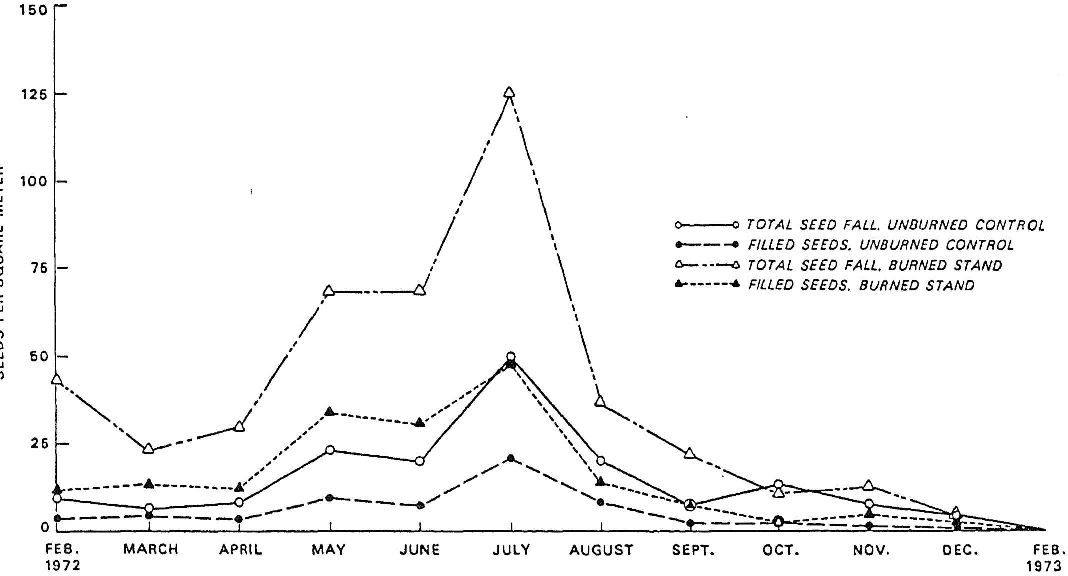

Figure 17.--Seed fall in burned and unburned black spruce stands from February 1972 to February 1973.

In the burned stand, large quantities of seed remained on the rees 1 year after the fire. Because of the large variation among rees in the burned and unburned stands, we cannot draw any conlusions concerning the percentage of seed dispersed the 1st year.

The real germination percentages indicate, as they did for seed ollected in seed traps during the 1st year of the study (table 18), hat fire reduced the quality of the seed contained in black spruce ones. Real germination averaged 90, 65, and 32 percent for seeds ollected from unburned trees and from 1- and 2-year-old burned rees, respectively. In the unburned control, 6 of the 7 trees 86 percent) had real germination of 90 percent or higher, whereas n the burned sample only 6 of 25 (24 percent) had real germination f 90 percent or higher (table 20).

Table 19--Quantity and quality of seed contained in cones of burned and unburned black spruce trees

Stand	Number of sample trees	Old cones[1]			New cones		
		Number per tree	Seeds per cone	Seeds per tree	Number per tree	Seeds per cone	Seeds per tree
Unburned control:							
Average	[2]10	208	24	5,000	278	40	11,996
Standard deviation		297	9	9,502	234	7	12,067
Range		5- 840	2-31	105-26,246	30-729	35-49	1,352-35,277
Burned stand, sampled in 1971:							
Average	15	623	15	9,060			
Standard deviation		468	9	8,474			
Range		160-1,660	2-32	850-28,537			
Burned stand, sampled in 1972:							
Average	10	1,168	10	12,352			
Standard deviation		875	3	11,560			
Range		93-2,111	5-13	850-27,020			

[1] Old cones appeared to be older than 1 or 2 years; new cones were produced in 1970 and 1971; all cones collected from the burned stands were classified as old.

[2] 10 trees were sampled, but only 7 had cones.

Although the seed testing rules do not recommend stratification for germination trials in black spruce, seed dormancy has not been adequately examined in northern genotypes of this species. Thus, it is possible that some of the poor germination could be the result of seed dormancy. Future tests should include stratification treatments until dormancy patterns are well known.

Seedling establishment.--The success of forest regeneration is determined by seed supply and the biotic and abiotic variables generally referred to as site conditions. Using seedling counts obtained from the vegetation analysis (table 21) and the seed fall data, we can gain some insight into the question of adequacy of seed supply, expressed in seedling percent (seedlings/100 viable seeds), for these site conditions.

Stand	Viable seeds/m^2	Number of seedlings/m^2	Seedling percent
BS-1L (light burn)	220	3.9	1.8
BS-1H (heavy burn)	114	1.2	1.0
BS-3H (heavy burn)	125	.3	.2

These seedling percents are quite low compared with those reported by Johnston (1972) for black spruce regeneration on various seed bed types in northern Minnesota. Because of the variability associated with both the seed fall and estimates of seedling density, the estimates of seedling percent also have a high degree of variability.

ble 20--Average quality of seed from black spruce trees in an unburned control and in a burned stand sampled twice after the 1971 Wickersham Dome fire

Tree number	Filled seed		Germinated seed		Real germination	
	Percent	Standard deviation	Percent	Standard deviation	Percent	Standard deviation
burned control:						
1	40.2	6.9	39.2	6.9	97.5	1.9
2	53.5	11.7	51.0	13.3	95.3	5.8
5	39.0	5.7	21.2	5.1	54.4	16.5
7	66.2	7.4	63.5	7.0	95.9	2.6
8	60.5	3.9	60.2	3.6	99.6	.8
9	53.0	5.1	47.8	4.9	90.1	2.9
0	73.0	7.7	72.8	8.2	99.6	.8
Mean	55.1		50.8		90.3	
rned stand, ampled in 1971:						
1	48.4	10.0	43.6	8.0	90.1	2.7
2	62.7	3.3	27.6	3.5	44.0	5.6
3	50.3	14.7	37.2	19.9	74.0	27.2
4	53.1	8.0	40.6	4.7	76.2	3.5
5	45.6	2.2	25.1	3.7	54.0	7.1
6	67.5	9.6	58.7	15.8	86.8	15.1
7	53.6	13.1	49.4	10.5	93.9	4.7
8	47.0	6.0	8.9	4.5	18.9	9.3
9	45.6	14.8	8.4	3.7	16.1	10.1
0	65.1	4.5	63.9	4.3	98.2	1.5
1	50.1	10.1	13.1	3.4	26.1	4.0
2	68.4	6.3	56.1	5.0	82.1	3.2
3	54.5	10.0	25.1	3.6	46.1	6.4
5	75.0	6.1	71.4	6.3	95.2	.7
6	30.6	2.1	24.9	4.8	81.4	12.3
Mean	54.5		36.9		65.5	
rned stands, ampled in 1972:						
8	25.8	10.4	1.8	1.0	7.2	2.9
9	38.2	5.2	5.0	.8	13.2	2.5
0	33.5	11.1	31.8	10.9	94.7	3.8
1	64.5	1.3	62.8	1.5	97.3	1.5
2	29.5	14.6	8.2	2.5	27.8	28.8
3	44.5	8.7	3.8	2.5	8.6	5.4
4	48.5	70.0	.8	1.0	1.5	2.1
5	52.8	4.0	32.5	8.7	61.1	13.0
6	36.0	6.0	2.5	1.9	6.5	4.4
7	39.0	10.5	0	0	0	0
Mean	41.2		14.9		31.7	

Table 21--Average number of seedlings in three burned black spruce stands for 3 years after the 1971 Wickersham Dome fire

Year	Stand		
	BS-1L	BS-1H	BS-3H
	Seedlings per square meter		
1971	0	0	0
1972:	3.2	1.4	.02
Standard deviation	3.1	2.0	.11
Range	0-25	0-6	0-.5
1973:	4.2	2.0	.04
Standard deviation	4.5	2.4	.17
Range	0-21	0-7	0-1
1974:	3.9	1.2	.3
Standard deviation	4.0	1.3	.9
Range	0-24	0-4	0-4

Autecology of 1st Year Postfire Tree Regeneration[19]

The type of regeneration after a fire is determined by the percentage of the organic mat consumed (this directly affects seed bed conditions and the material available for vegetative reproduction), the ability of the preburn vegetation to reproduce, and the supply of seed within or adjacent to the burn. The objectives of this study were to examine the dynamics of tree seed germination and first growing season survival on the various seed beds in the burned stands, and to record natural regeneration on randomly selected surfaces of the burn.

Artificial seeding.--The primary site for the artificial seeding study was about 3 km from the Wickersham Dome ridgetop study area (stands BS-3C and BS-3H). A north and south slope (same drainage) were selected for plot establishment; 10 plots were seeded on each aspect. Each plot consisted of five rectangular subplots (5- by 30-cm). The two side subplots and the middle subplot were seeded with 1,000 seeds of either black spruce, white spruce, or paper birch. The black spruce seed were collected from trees in the burned area and had an average germination of 41 percent.

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[19] This section was prepared by S. F. Clautice, Forester, Alaska Division of Forest, Lands, and Water Management, Fairbanks; J. C. Zasada, Silviculturist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska; and B. J. Neiland, Professor, School of Agriculture and Land Resources Management, University of Alaska, Fairbanks.

The birch and white spruce seeds were collected in the Bonanza Creek Experimental Forest at an elevation of about 200 m. Laboratory germination was 68 and 27 percent for white spruce and birch, respectively. Plots were seeded in early June 1972 on mineral soil, ash, and charred surfaces.

The second part of the artificial seeding study was conducted on a fireline adjacent to the ridgetop study site at Wickersham Dome. All organic matter had been removed, leaving a bare mineral soil surface. White spruce, black spruce, and birch were seeded in October 1971. Birch plots were seeded with 300 seeds (germination 65 percent), white and black spruce with 200 seeds (germination 75 and 65 percent, respectively). Observations were made weekly until the first seedling was observed on June 21, 1972; seedling counts were repeated on July 21 and August 20.

The experiment consisted of three study blocks. Within each block, each species was replicated three times. Each replication consisted of a 1-m^2 plot; within this plot two 25-cm-diameter circular plots were located. One of these plots was covered with hardware cloth; the other was unprotected.

Germination of birch exhibited a similar pattern on both aspects; i.e., a peak in mid-June to late June with relatively little additional germination. Both white and black spruce exhibited a similar response on the north slope; however, peak activity was later than that observed for birch. On the south slope, spruce germination did not exhibit a distinct peak (fig. 18). These differences in response of species to aspect are believed related to hot, dry surface conditions which occurred on the south slope in late June (Clautice 1974).

At the fireline site, no germination was observed before June 14 on either the protected or unprotected plots. During the week prior to June 21, approximately 80 percent of the annual germination occurred in the protected plots. In the unprotected plots fewer germinants were observed; however, a higher percentage (90) were from the period prior to June 21 (table 22). The relatively low number of seedlings produced indicate that loss of seed on unprotected plots was significant. Survival of germinants through early September was similar on north and south slopes. Survival of birch was lowest, followed by white spruce and black spruce. Percentage of survival, however, depended on the germination date. June germinants exhibited poor survival on the south slope; survival of July and August germinants was generally higher. On the north slope, first growing season survival was highest for June and August germinants (fig. 19). On the fireline sites, seedlings germinating prior to June 21 contributed the majority of the seedlings to the August 21 population (table 22).

Moisture and temperature are two important factors regulating seed germination. Average daily maximum and minimum mineral soil surface temperatures during peak birch germination on the south slope were 7°C and 24°C; on the north slope, 4°C and 17°C. During the hottest period of the summer (June 27 to July 11), when mortality reached a maximum on the south slope, average daily maximum surface temperatures were 29°C on mineral soil, 39°C on

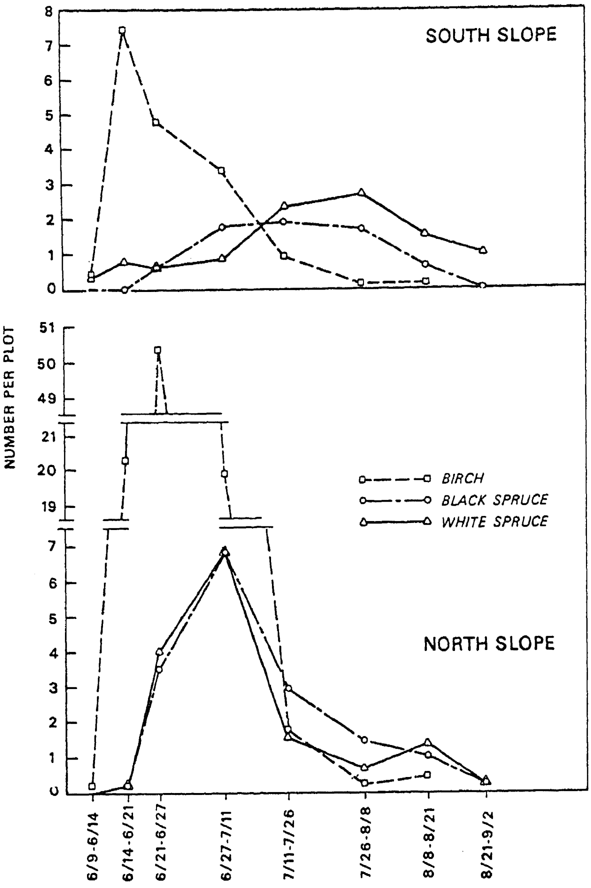

Figure 18.--Weekly germination of seeded birch, black spruce, and white spruce on north and south slopes 1 year after fire (1972).

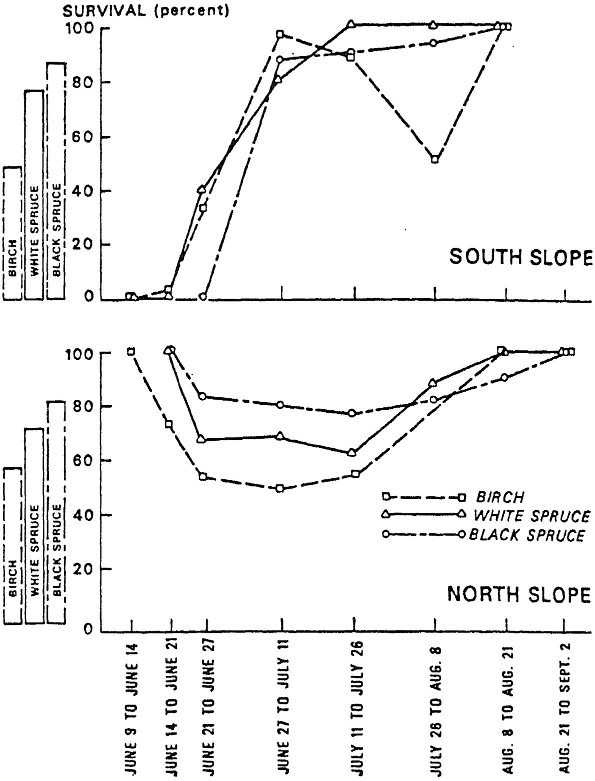

Figure 19.--Percent of birch, white spruce, and black spruce seedlings surviving to September by date of germination (1972).

Table 22--Germination and survival of birch and white and black spruce seedlings on mineral soil on 3 dates during the 2d growing season after a wildfire, Wickersham Dome study area

Species and number	June 21		July 21				August 21			
	Protected[1]	Unprotected	Surviving June 21 seedlings[2]	New seedlings		Total[2]	June 21 seedlings[2]	July 21 seedlings[2]	New seedlings		Total[2]
				Protected	Unprotected				Protected	Unprotected	
Birch:											
1	0	3.5	0 / 1.0	0.7	0	0.7/ 1.0	0 / 1.0	0 /0	0.3	0	0.3/ 1.0
2	5.0	4.0	2.7/ 2.3	.7	0	3.4/ 2.3	1.2/ 2.3	.7/0	0	0	1.9/ 2.3
3	3.7	1.0	3.7/ .3	.3	.3	4.0/ .6	3.3/ .3	.3/ .3	0	0	3.6/ .6
White spruce:											
1	25.3	3.0	24.3/ 1.7	17.3	.7	41.6/ 2.4	22.3/ 1	11.3/ .3	0	0	33.6/ 1.3
2	28.7	.3	23.7/ .3	7.7	0	31.4/ .3	21.0/ .3	5.0/0	0	.3	26.0/ .3
3	35.3	25.0	22.3/22.3	2.0	0	24.3/22.7	18.7/19.7	1.3/ .3	0	0	20.0/20.0
Black spruce:											
1	3.7	0	3.0/ 0	.7	0	3.7/ 0	1.3/ 0	0 /0	0	.3	1.3/ .3
2	2.0	0	1.3/ 0	1.7	0	3.0/ .3	1.3/ 0	0 /0	1.3	0	2.6/ 0
3	11.0	2.0	8.0/ 1.3	1.0	0	9.0/ 1.3	6.3/ 1.3	.6/0	0	.3	6.9/ 1.6

[1] Seeded area protected by hardware cloth.

[2] Protected/unprotected seedlings.

ash, and 41°C on charred moss. Absolute maximum temperatures recorded during this period were 41°C, 68°C, and 77°C on mineral soil, ash, and charred moss, respectively. Soil moisture was not measured; however, mineral soil had a consistently moist surface on the north slope.

Natural revegetation.--Significant differences existed between surface condition, species composition, and major type of reproduction between the north and south slopes (tables 23 and 24). A chi-square test of the differences in the density values of the June species among the surfaces showed the surface classification to be significant at the 0.05 level. Surfaces with the largest amount of similar vegetation were "flat charred moss" and the more deeply burned "convoluted burned moss." Both these conditions were included in the general moderately burned category.

Effects of Fire on Arthropod Distribution[20]

The sampling of arthropod populations in 1972 and 1973 was limited to 10 pit traps in the burned and the unburned control areas. The pit traps were checked weekly for 9 weeks, and the trapped arthropods were collected and stored in 80 percent ethanol. The specimens were separated and the data analyzed according to five major categories: spiders, Collembola, mites, Coleoptera, and other arthropods.

The total number of arthropods collected in 1973 was significantly lower than similar collections from 1972 (table 25). The unburned control and burned areas produced 44 and 23 percent fewer arthropods, respectively, in 1973. In both years, however, the burned areas produced more specimens than the unburned control areas, which indicates either a higher population of arthropods or higher arthropod activity in the burned areas and therefore a greater chance of capture.

There was a significant decrease in the percentage of mites (46), Collembola (43), and Coleoptera (72) captured in 1973 and no significant change in the "other arthropods" category. The number of spiders captured in burned areas in 1973 was 1.3 times higher than in 1972, and in 1973 spider numbers were 3.0 times higher in the burned area than in the unburned control. The decrease in most arthropod populations in burned areas compared with the increase in spider populations can be attributed to predation by spiders. Spider predation would be higher in the burned area because of sparse ground vegetation which offers protection to prey species.

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[20] This section was prepared by R. C. Beckwith, Principal Insect Ecologist, Forestry Sciences Laboratory, Corvallis, Oregon, and R. A. Werner, Research Entomologist, Institute of Northern Forestry, Fairbanks, Alaska; both men are with USDA Forest Service, Pacific Northwest Forest and Range Experiment Station.

after the Wickersham Dome fire

Species	Origin of reproduction[1]	Month	Density				Total area	
			Lightly burned moss[2]	Flat charred moss[3]	Convoluted burned moss[4]	Ash[5]	Density	Frequency
			Stems per square meter					Percent
Alnus	v	June	1.56	0.05	0	0	0.31	6
crispa		Sept.	1.56	.99	0	0	.89	12
Betula	v	June	0	0	7.58	0	.61	3
papyrifera		Sept.	0	0	7.95	0	.64	3
Calamagrostis	s	June	10.75	7.70	0	0	6.37	41
canadensis		Sept.	24.09	17.96	.38	0	14.45	44
Corydalis	s	June	.52	.42	9.85	5.27	1.88	32
sempervirens		Sept.	1.39	1.04	12.88	6.09	2.79	47
Epilobium	s	June	.17	.21	0	.61	.24	15
angustifolium		Sept.	.17	.47	0	.81	.42	18
Rosa	v	June	0	.10	0	0	.06	3
acicularis		Sept.	0	.42	0	0	.24	9
Rubus	s	June	0	.05	0	3.65	.58	21
idaeus		Sept.	.35	.10	0	3.04	.58	32

[1] v = vegetation; s = seed.

[2] Only upper surface of moss charred.

[3] Deeper charring in moss layer (moderately burned).

[4] Variable burning in moss layer (moderately burned).

[5] Moss layer consumed, only ash remaining on surface of mineral soil (heavily burned).

Table 24--Density of vegetation on 7 burned surfaces on the north slope during the 2d growing season after the Wickersham Dome fire

Species	Origin of reproduction[1]	Month	Density							Total area	
			Living moss[2]	Dead moss[3]	Lightly burned moss[4]	Flat charred moss[5]	Convoluted burned moss[6]	Ash[7]	Mineral soil[8]	Density	Frequency
			Stems per square meter								Percent
Calamagrostis	v	June	0	4.12	3.04	4.85	6.36	1.23	0	3.00	38
canadensis		Sept.	0	6.18	4.15	8.44	7.63	1.23	0	4.31	47
Epilobium	s	June	0	0	0	0	0	0	0	0	0
angustifolium		Sept.	0	0	.18	0	0	0	0	.03	3
Equisetum	v	June	17.11	13.92	19.83	22.89	23.41	37.42	18.64	21.74	97
pratense		Sept.	18.42	18.04	23.34	28.28	25.45	43.56	28.81	25.97	97
Ledum	v	June	38.16	15.46	2.49	0	0	0	0	2.77	31
groenlandicum		Sept.	38.16	23.71	4.70	.09	.51	0	0	4.16	38
Marchantia	s	June	0	0	0	0	0	0	[9] 6.80	[9] .12	3
polymorpha		Sept.	0	0	0	0	0	0	[9] 16.90	[9] .32	3
Oxycoccus	v	June	81.58	0	0	0	0	0	0	2.00	3
microcarpus		Sept.	78.95	10.82	0	0	0	0	0	2.61	6
Picea	s	June	1.32	0	0	0	0	0	0	.03	3
mariana		Sept.	1.32	0	0	0	0	0	0	.03	3
Polygonum	v	June	0	0	.18	0	0	0	0	.06	3
alaskanum		Sept.	0	0	.18	0	0	0	0	.06	3
Polytrichum sp.	s	June	0	0	0	0	0	0	0	0	0
		Sept.	0	0	0	.36	.25	3.68	0	.35	9
Rosa	v	June	0	0	0	0	0	0	0	0	0
acicularis		Sept.	0	0	0	.36	0	0	0	.13	3
Rubus	v	June	3.95	2.06	5.81	.63	.25	0	0	3.52	41
chamaemorus		Sept.	3.95	5.15	8.12	1.89	.25	0	0	3.97	56
Rubus	s	June	0	0	0	0	0	.61	0	.03	3
idaeus		Sept.	0	0	0	0	0	.61	3.39	.10	6
Spiraea	v	June	0	0	.28	0	0	0	0	.10	3
beauverdiana		Sept.	0	0	.37	0	0	0	0	.13	3
Vaccinium	v	June	0	1.03	.18	0	0	0	0	.13	6
uliginosum		Sept.	0	1.03	.18	0	0	0	0	.13	6
Vaccinium	v	June	0	161.34	10.70	.18	0	0	0	3.90	41
vitis-idaea		Sept.	0	162.89	10.88	.18	0	0	0	4.06	41

[1] v = vegetation; s = seed.

[2] Unburned.

[3] Moss scorched and killed by heat.

[4] Only upper surface of moss charred.

[5] Deeper charring in moss layer (moderately burned).

[6] Variable burning in moss layer (moderately burned).

[7] Only ash remaining on surface of mineral soils (heavily burned).

[8] Mineral soil exposed by fireline construction.

[9] Expressed in percent cover.

Table 25--Numbers of arthropods collected from pit traps, Wickersham Dome, 1 and 2 years after a 1971 wildfire[1/]

Year and area	Spiders	Mites	Collembola	Coleoptera	Other arthropods	Total
1972:						
Unburned control	320	178	1,142	53	454	2,147
Heavy burn	557	701	866	113	382	2,619
1973:						
Unburned control	249	167	500	9	270	1,195
Heavy burn	736	381	494	32	286	2,029

[1/] Based on 9 similar collection dates for each year.

Numeric Response of Microtine Rodents After Fire[21]

Postfire population response of the northern red-backed vole (*Clethrionomys rutilus*) and the tundra vole (*Microtus oeconomus*) was investigated during a yearlong live trapping from June 2, 1972, through June 18, 1973, in the severely burned area and adjacent unburned control area of black spruce taiga at the Wickersham ridgetop site (plots BS-3H and BS-3C).

These areas were trapped again in the fall of 1973 and the subsequent summers of 1974, 1975, and 1976. The density information summarized here pertains to the 1972-73 year and the summer of 1974. Other aspects of this work have been presented by West (1977) and a more exhaustive treatment in a Ph.D. thesis (West 1979).

All population measurements were taken on two parallel live-trapping grids, one in the burned area and one in the unburned control area. Both grids consisted of 96 large folding aluminum live traps, spaced at 10-m intervals in an 80- by 120-m configuration along the ridgetop. With a 5-m boundary strip assumed, this spacing produced a trapping area of 0.96 ha. The traps were baited with rolled oats and operated during the night hours (about 10 p.m. to 8 a.m.) for 3 consecutive days every 2 weeks. Basic information collected at each capture included weight, sex, point of capture, and reproductive condition. Toes of voles were clipped for individual recognition.

The overall trends in size of populations for northern red-backed vole and tundra vole for 1972-74 are shown in figure 20. The most striking feature of the population density of northern red-backed vole is its pronounced annual cycle. Breeding seasons

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[21] This section was prepared by S. D. West, graduate student, Museum of Vertebrate Zoology, University of California, Berkeley.

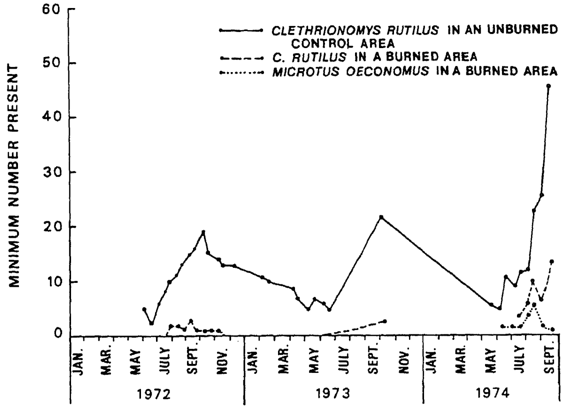

Figure 20.--Population trends for the northern red-backed vole and the tundra vole in an area burned in 1971 and an adjacent unburned control area.

are periods of consistent increase, characteristic of populations with overlapping generations. These peak densities are intermediate in terms of the peak densities observed for northern red-backed vole in interior Alaska white spruce forests (Pruitt 1957). The breeding seasons for northern red-backed voles extended from May to September; most activity was concentrated in June, July, and August. The adult sex ratio in the population was approximately one to one.

In the unburned control area, the spring and fall density in both 1972 and 1973 were similar. The fall 1973 trapping period probably caught all but two or three voles that were on the grid at that time. The slightly larger spring 1974 population might indicate improved winter survival compared with survival in 1973, or that the spring 1974 immigration rate was higher than 1973, resulting in a larger population in June 1974. A high recapture rate during the fall 1973 trapping periods and the concomitant absence of reproductively active voles suggest that most voles on the study area had been marked by the 1st week in October. Only 1 vole out of 22 marked in the fall of 1973 was captured the next spring, however, which indicates an influx of unmarked adults. This pattern was also seen in spring 1973 but to a lesser extent (West 1974).

On a seasonal basis, mortality for northern red-backed vole was highest in the fall, lowest in winter, and intermediate in summer. Spring rates were difficult to determine because of small size of population.

The substantial increase in density in fall 1974 was not due to an extended breeding season relative to the preceding 2 years. The absence of pregnant, lactating, or estrous females and the absence of scrotal males indicated that reproduction had ceased in both years by the end of September. In fact, the number of reproductively active females was similar from July through September each year. The difference in density was most likely due to increased survival of juveniles in late August and September. The density in 1975 was nearly identical to that of 1974, and the density in 1976 was about the same as 1972 and 1973. Minimum annual densities have all been fewer than 10 voles, lending force to the arguments of Whitney (1976) that the northern red-backed vole is not cycling in the classic microtine fashion in interior Alaska. The annual cycle of maximum density appears to be determined by the survival of juveniles from the fall generation.

In 1972, activity of red-backed voles in the heavily burned area was very low over the first postfire growing season and was confined to the late summer-early winter period from late July to early November. Only seven voles were caught in the burned area during that time; 2 of these accounted for 12 of the 18 total captures in the burned area, and these 2 were caught in the unburned control area as well. The fall 1973 trapping indicated essentially the same density as that of the previous fall. None of the three voles known to be alive in fall 1973 was recaptured; the spring 1974 population consisted of immigrants. In 1973 the red-backed voles abandoned the burned area as they had the preceding winter. No red-backed voles were caught in the burn until the latter part of July 1974, when the population in the burned area increased substantially. Both postpartum females and very young voles were caught, which indicated breeding on the burned area. Voles overwintered in the burned area for the first time in 1974.

The tundra vole (*Microtus oeconomus*) was captured only one time (August 1972) in the unburned control area and was not captured in the burned area until the spring of 1974. Observations in the burned area immediately after snowmelt in 1974 indicated that tundra voles were present prior to the thaw. Several runways and burrows were found, primarily in moist, low-lying zones and in root tangles. These animals could have been either overwintering animals not caught in fall 1973 or, more likely, immigrants during early spring 1974. As shown in figure 20, the tundra vole population increased until mid-August and declined thereafter. The possibility exists that the decline was due to the increasing population of red-backed voles present on the burned area. As plant succession proceeds on the burned area, the vegetational composition will more closely resemble the habitat requirements of the tundra vole, and a resident population should become established. Trapping in several successional areas where time since last fire is known indicates that peak tundra vole densities at Wickersham Dome can be expected in 4-12 years from 1974, depending on the rate of plant succession.

Habitat Utilization By Snowshoe Hares In Burned and Unburned Black Spruce Communities[22]

The impact of snowshoe hares on secondary succession after fire has not been determined in the taiga of interior Alaska.

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[22] This section was prepared by J. O. Wolff, Research Associate, Museum of Vertebrate Zoology, University of California, Berkeley, and Institute of Northern Forestry, Fairbanks, Alaska; C. T. Cushwa, Wildlife Biologist, Forest Environment Research, USDA Forest Service, Washington, D.C.; and K. P. Burnham, Biometrician, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

The 1971 fire at Wickersham Dome and the adjacent, unburned 70-year-old black spruce stand presented an opportunity to study habitat utilization by snowshoe hares in the two communities. The major objectives of this portion of the study were to compare population densities of snowshoe hares in the burned and unburned control stands and to relate these to availability of food and cover. Food habits and browse intensities by snowshoe hares were also recorded to determine the impact of snowshoe hares on forest regeneration and plant succession. Wolff (1977) reported on the snowshoe hare project at the Wickersham Dome study area.

In summer 1972, two 40-ha grids of live-traps were established, one in the burned area and one in the adjacent, unburned control area. Each grid consisted of 100 traps in a 10 by 10 array with 60 m between any two traps. In 1974, each grid was reduced to an 8 by 10 array of traps encompassing an effective area of 34 ha. Single-door traps of wire were made according to the method described by Cushwa and Burnham (1974) and were baited with alfalfa cubes. Trapping periods varied from 6 to 10 consecutive days and were initiated in November 1972. Spring trapping was conducted in April when the hares were still on a winter diet. The ears of captured hares were tagged, and the hares were weighed and sexed prior to release. Individual traps were numbered to identify exact locations of captures for movement calculations. Vegetation was sampled in both areas to determine densities of trees and shrubs and percent ground cover of low shrubs, herbs, mosses, and lichens.

In the Wickersham Dome fire, hares consumed virtually all the postfire willow sprouts during September following the July burn (fig. 21). During the winter of 1971-72, they consumed charred bark of black spruce, aspen, and birch (fig. 22). The second winter after the fire (1972-73), hares consumed all the aspen sucker regrowth in several stands (fig. 23). From 1971 to 1973, 100 percent of the available hardwood browse (willow, alder, and aspen) was consumed in the unburned control and a 200-m strip of the burned area paralleling the unburned area (table 26). From 1973 to 1976, browse intensity by snowshoe hares decreased concurrently with an overall decline in the hare population.

The high intensities of browsing on willow and aspen for 2 years after the fire stimulated lateral branching which increased vegetative growth. Current annual growth was removed each winter, but the long-term effects were increased production of aboveground biomass (Wolff 1978a).

The results from live-trapping at Wickersham Dome from 1972 to 1976 are shown in table 27 and illustrated in figure 24. We used the Schnabel and Lincoln indices with a 95-percent confidence interval to estimate populations (Giles 1969).

In the fall of 1972, 74 hares were live trapped, tagged, and released in the unburned control; only 3 hares were caught in the burned area. A population estimate for the unburned control for 1971 would be about 200 animals (Ernest 1974). By April 1973 the population of hares in the burned area had increased to 15, 13 of

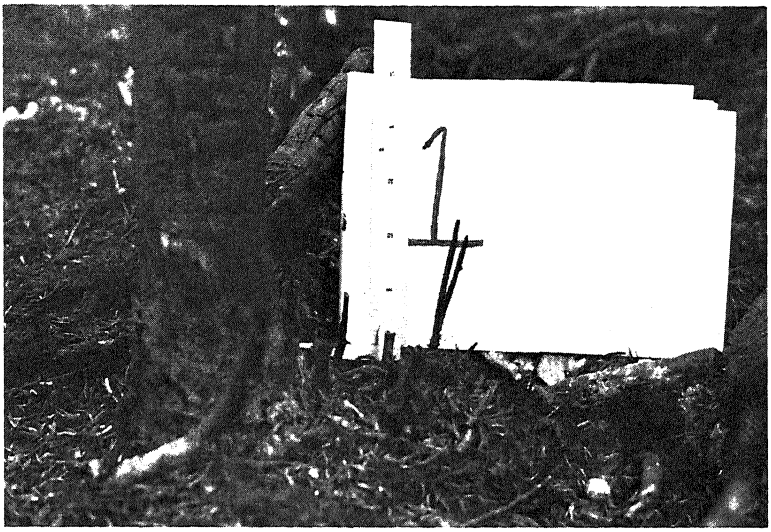

Figure 21.--Hares consumed virtually all the willow sprout regrowth during September after the July wildfire.

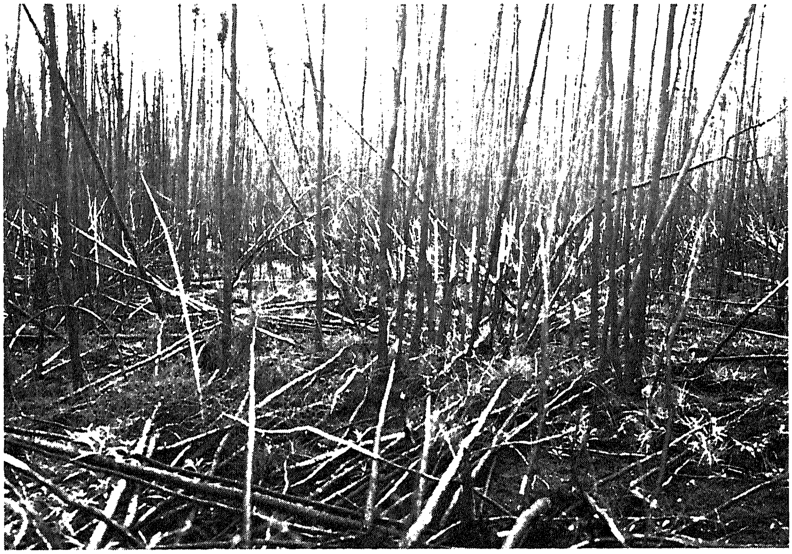

Figure 22.--Evidence of browsing by snowshoe hares on charred black spruce at the 1971 Wickersham Dome fire site.

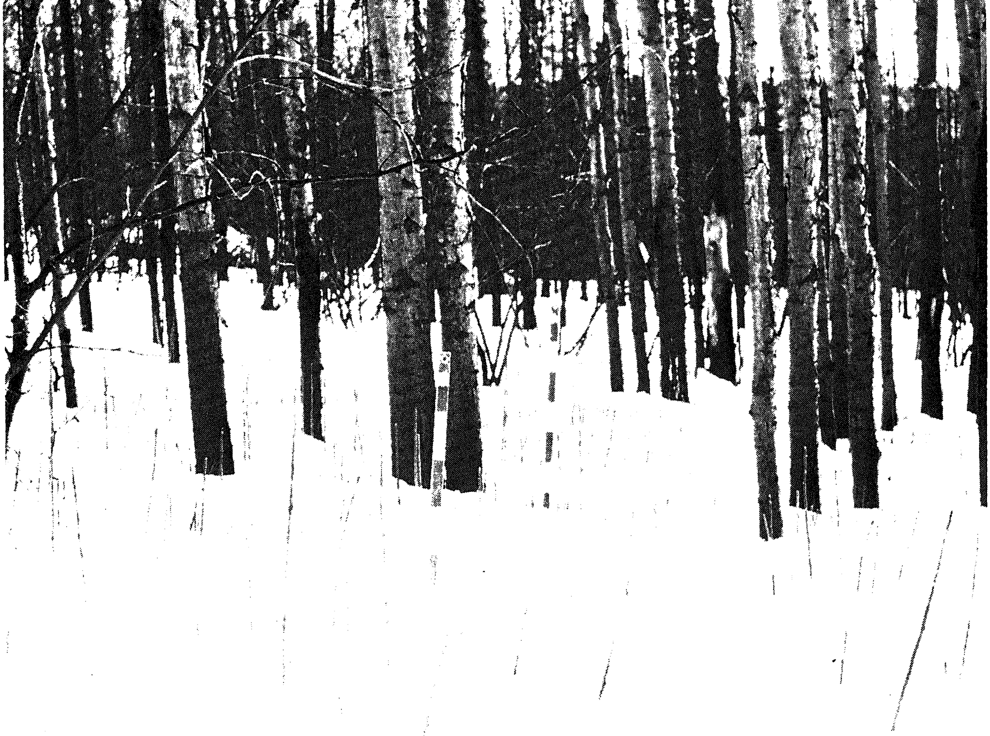

Figure 23.--Consumption of aspen regrowth by hares the second winter after the 1971 Wickersham Dome fire.

Table 26--Intensity of browsing by snowshoe hares at the Wickersham Dome study site for 5 years after a 1971 wildfire[1]

Area	1971-72	1972-73	1973-74	1974-75	1975-76
	- - - - - - - - -	- - - - -	-Percent-	- - - - -	- - - - - - - - - -
Burned	100	100	3 ± 1.7	0	0
Unburned control	100	100	45 ± 3.3	4 ± 2.3	1 ± 1.2

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[1] Plus or minus signs indicate standard error of the mean.

Table 27--Population estimates of snowshoe hares for the Wickersham Dome unburned control, based on data of recaptured, marked hares[1/]

Trapping period	Total captured	Total recaptured	Total marked animals	Population estimate			
				Schnabel[2/]		Lincoln[2/]	
	- - - - -Number- - - - -			Average	95-percent confidence interval	Average	95-percent confidence interval
Nov. 1972	164	90	74	85	69-105	78	52-112
Apr. 1973	221	152	69	67	57-79	70	46-102
Apr. 1974	117	74	43	42	33-52	45	29-65
July 1974	44	21	22	27	16-41	29	6-108
Sept. 1974	19	9	10	12	5-23	10	1-95
Nov. 1974	12	2	11	26	4-147	24	2-468
Apr. 1975	5	1	4	8	1-156	6	0-117
Aug. 1975	12	8	4	4	2-9	4	1-15
Nov. 1975	4	2	4	5	0-14	5	0-39
Apr. 1976	17	10	9	8	4-20	7	3-16
Aug. 1976	54	29	21	20	14-27	23	17-29

[1/] Population estimates are number of hares per 34 hectares.

[2/] Giles (1969).

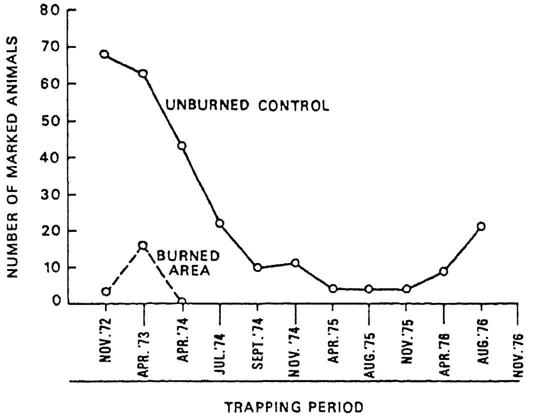

Figure 24.--Number of marked snowshoe hares caught in the burned area and the unburned control at Wickersham Dome after a 1971 wildfire, 1972-76.

which were marked transients from the unburned control; the number of animals caught in the control was 69, 31 of which were recaptured from the fall population. Field observations revealed that hardwood browse had become limited in the unburned control, and hares were forced to leave the protection of the mature forest and enter the open burn in search of food. Survival rates of marked animals were much greater in the dense black spruce stand than in the burned area or the more open portions of the spruce stand.

One year later, in the spring of 1974, only 43 hares were tagged in a 7-day trapping period in the unburned control and 1 in the burned area. Hares had been seen crossing from the control into the burned area, but there appeared to be no permanent residents in the burned area. Quantitative measurements revealed that there was enough hardwood browse in the unburned control to maintain a population at that level. Browse intensity in the burned area was only 3 percent, whereas in the unburned control about 45 percent of the available browse was consumed. By July 1974, only 22 hares were caught in the unburned control; by November, only 11. No hares were caught in the burned area from 1974 to 1976. The low number of hares marked in November 1975 was thought to be an underestimate caused by a change in trapping procedures. The population reached a low of 4 hares in April 1975 but increased to 21 by August 1976.

The population decreased from a high of six hares/ha in the fall of 1971 to a low of 0.12 hare/ha in April 1975. The decline was gradual but continuous through the summer reproductive seasons as well as during the winter. The decline may have been initiated by decreased quantity and quality of forage during the peak population densities from 1971 to 1973, which resulted in reduced physiological fitness and eventual starvation. The continued decline from 1973 to 1975 was probably due to increased rates of predation which increased hare mortality (Wolff 1977).

Food habits of snowshoe hares were determined by microscopic analysis of stomach contents (Wolff 1978b). Blueberry, lowbush cranberry, fireweed, and horsetail made up 47 percent of the spring diet; and leaves of birch, willow, rose, and other deciduous shrubs made up 76 percent of the summer diet (fig. 25). Trap results indicate that hares migrate seasonally in response to this change in diet. In the summer, hares prefer open areas where blueberry, lowbush cranberry, and other herbaceous plants are more plentiful. During the winter when the herbs and low shrubs are covered with snow, hares move back into the dense black spruce thickets where they feed on spruce needles and bark and twigs of birch, willow, and alder.

Populations of snowshoe hares in Alaska and throughout the boreal forests of North America appear to fluctuate on a 10-year cycle. Densities may show a 60-fold difference from high to low years and range from 800 to 12 hares/km^2. The study of snowshoe

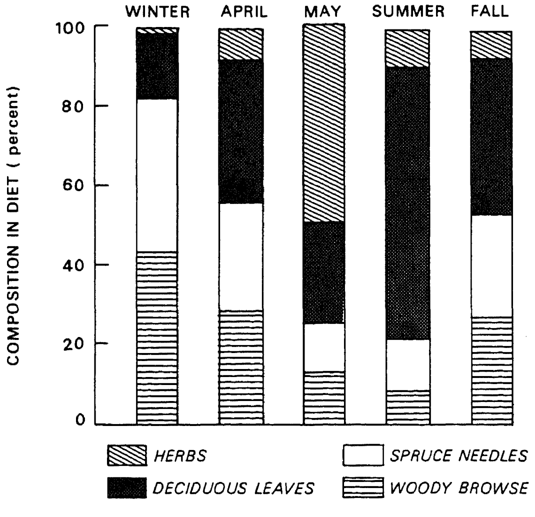

Figure 25.--Diet of snowshoe hares at different times of the year.

hares at Wickersham Dome was conducted during the peak and declining phases of the cycle. When the population densities were low, hares remained in dense black spruce or willow-alder thickets where food and cover were plentiful. During high densities when hares exceeded their overwinter food supply in preferred habitat (1971 through 1973), they invaded more open and recently burned areas to forage on new growth of woody browse plants. During these high densities, hares occupied all suitable habitat, and browse intensity reached 100 percent. Excessive browsing by hares had an adverse effect on regeneration of woody plants from 1971 through 1973. Long-term effects of excessive browsing may, however, result in increased production of woody browse because of lateral branching of browsed stems. In conclusion, we feel that hares have the greatest impact on regeneration of trees and woody shrubs for only a 2- to 3-year period in a 10-year cycle.

SUMMARY[23]

The Wickersham Dome fire occurred in late June 1971 and burned over approximately 6 300 ha. The fire, which was typical of interior Alaska wildfires, was brought under control after tractor construction of 113 km of firelines and aerial application of some 242 000 liters of fire retardant. Before the fire, the area was mostly covered with black spruce stands, ranging in age from 50 to 125 years. The forest floor was made up of a continuous mantle of mosses, principally feather mosses with some *Sphagnum*. Stands of quaking aspen occurred on some slopes and were characterized by a striking decrease in moss cover. The area is one of relatively gentle relief, with rounded ridges and elevations ranging from 210 to 980 m. Soils are silt loam and formed in wind-deposited loess. Ridges and upper south slopes are free of permafrost; in other locations, soils generally have a permafrost table within 40 to 50 cm of the surface.

Shortly after the fire was controlled, eight plots were established in black spruce areas for intensive study of the ecological effects of the fire. These plots were arranged in three sets located on the ridgetop and middle and lower slopes. Two plot sets consisted of an unburned control, a lightly burned stand and a heavily burned stand. The other set (on the ridgetop) contained only a heavily burned stand and an unburned control. Three additional plots were established 1 year after the fire (June 1972)--a heavily burned stand and an unburned control in aspen, plus another unburned control in black spruce.

Although certain portions of this study are continuing, results reported here are mainly for the first 3 years after the fire (1972-74).

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[23] This section was prepared by C. T. Dyrness, Supervisory Soil Scientist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, Fairbanks, Alaska.

Examination of soil after the fire indicated that moist lower forest floor layers had minimized the impact of the fire on the soil. Other than in firelines, patches of bare mineral soil were rare, even in heavily burned areas. Measurements of burned forest floor thickness indicated greatest fire effects occurred where forest floors were thickest; starting with an unburned thickness of 28.7 cm, average reductions were 10.3 cm for heavily burned areas and 5.7 cm for lightly burned areas. In other words, even in heavily burned areas an average of almost two-thirds of the forest floor remained after burning. Weight and bulk density of forest floor samples were also determined; however, no statistically significant effect of the fire could be determined. In view of the rather shallow depth of burning in the forest floor, it is perhaps not surprising that the burning had no discernable effect on chemical properties of the mineral soil. Cation exchange capacity, pH, exchangeable Ca, Mg, and K, available P, and total N were determined on samples from the surface 15 cm of mineral soil in burned and unburned areas, but there were no significant differences between the areas.

The reduction of forest floor thickness and blackening of the surface by fire causes higher soil temperatures. Most studies have indicated that surface soils which have been recently burned warm up more quickly at the beginning of the growing season and are substantially warmer than unburned soils. This relationship also proved true in the present study; 1 year after the fire, the soil temperature at a depth of 10 cm reached a maximum of 10.5°C on July 20 in a burned area. In the unburned control, the maximum temperature was only 6°C, and the peak was delayed until September 13.

In interior Alaska one of the most important consequences of increases in soil temperature caused by fire is stepped up permafrost melting. Such thawing substantially increases the amount of available soil nutrients and soil water. On the Wickersham Dome fire site, change in the rate of thawing was particularly dramatic; 1 year after the fire, the active layer was 62 cm thick in the burned area and only 42 cm in the unburned control. By the 3d year, the active layer had increased to 84 cm in the burned area and 47 cm in the unburned control. On firelines, where virtually all surface insulation had been removed, the rate of permafrost drop was almost doubled; 3 years after the fire, the active layer in the firelines was 132 cm thick.

Despite substantial changes in the microclimate caused by fire, especially in and around the forest floor, studies of aboveground macroclimatic parameters did not disclose measurable differences between burned and unburned areas. For example, patterns of snow accumulation and snowmelt were not substantially different in a burned area than in an unburned area. Likewise, standard measurements of air temperature did not disclose a difference between burned and unburned areas.

Unfortunately, little work has been done in interior Alaska on the effects of wildfire and fire suppression on quality of stream water. There are speculations that increases in erosion and runoff caused by fire are at a minimum in northern areas, but data to back this up are lacking. To obtain an indication of the effects of the Wickersham Dome fire on streams, we sampled Washington Creek both above and below the fire on the day the fire was controlled, 1 week after control, and 2 weeks after. The day the fire was controlled, suspended sediment content of the stream was about 300-500 mg/liter. After the Bureau of Land Management constructed water bars on the firelines, the sediment content dropped to a maximum value of 19 mg/liter 1 week after control. A small increase in concentration of phosphate in the stream water was measured after applications of retardants; however, concentrations of nitrogen were the same above and below the burned area.

Development of vegetation after the fire was, as would be expected, closely tied to severity of the fire. On a lightly burned black spruce plot 40 percent of the ground vegetative cover was still alive after the fire. This increased to a total of 70 percent cover 3 years after the fire (August 1974). Considerable amounts of mosses and *Cladonia* lichens survived the fire and greatly contributed to its rapid postfire recovery. Although many black spruce seedlings and saplings were alive after the fire, the majority of these died during the subsequent 3 years, leaving only 61/ha. Spruce seedlings, however, germinated in large numbers; nearly 40,000/ha were recorded in 1974.

In contrast, recovery of vegetation on heavily burned black spruce plots has been much slower. No climax mosses and lichens survived the fire; consequently, moss and liverwort cover was low after 3 years and was made up exclusively of the invaders *Marchantia polymorpha* and *Ceratodon purpurea*. Herbaceous cover recovered at a faster rate and reached about 15-20 percent after 3 years--substantially higher than that in the unburned control. Principal herbaceous species in these early postfire years were *Equisetum sylvaticum* and *Epilobium angustifolium*, both present in the unburned control. Response of shrubs to fire on heavily burned plots has been mixed. On one plot, *Salix scouleriana* sprouted rapidly after the fire and by the 3d year had three times the basal area of the unburned control. In other areas, however, sprouting of shrubs was less vigorous; after 3 years, densities were still appreciably lower than on the unburned control.

One of the most significant findings of our studies of revegetation was that very few of the plant species appearing soon after a fire are invaders. The great majority are species that were present in the prefire stand and reproduce vegetatively from underground plant parts surviving the fire. This process of vegetative reproduction was especially striking in the heavily burned aspen stand. During the 1st year after the fire, there were nearly 200,000 aspen shoots per hectare. *Rosa acicularis* also greatly increased its cover after the fire by means of stem and root shoots. Because most of these underground parts that are active in postfire reproduction are located in the organic forest floor layers, depth of burning becomes of overwhelming importance in controlling the nature of early successional stages. With increasing depths of burn, more and more of these structures will be eliminated until, with bare mineral soil, only sparse vascula plant cover will be present during the 1st year after burning.

Some workers have speculated that, as a result of warmer site and accelerated nutrient cycling, early stages of postfire succession in the Alaska taiga would be marked by increases in prima productivity. To test this assumption, we undertook a limited sampling program of annual biomass and litter fall at the Wicker Dome study site. Biomass at the end of the 3d year after the fi was extremely variable, ranging from a low of 33 g/m^2 on a heavi burned black spruce plot to a high of 804 g/m^2 on the heavily burned aspen plot. Although approximately 60 percent of the top figure was contributed by aspen sprouts, *Ceratodon*, *Marchantia*, *Epilobium*, and *Calamagrostis* also had sizable amounts of biomas Despite the fact that the aspen sprouts were heavily browsed, th continued to grow well and the browsing apparently encouraged th development of lateral branches. This very high production of available browse illustrates the possible value of fire in the production of wildlife habitat.

To fully understand the effects of fire on nutrient cycling, we must measure both litter fall and rates of litter decompositi In the burned black spruce plots, litter fall originated primari from standing dead trees and willows. Litter fall in lightly burned plots was heaviest the 2d year after the fire when it averaged about 20 g/m^2 (versus 10 g/m^2 in the unburned control, and 7 g/m^2 in heavily burned plots). During the 3d year after burning, litter fall decreased in both burned black spruce areas As would be expected, litter production in the burned aspen plot was very high (118 g/m^2 per year) because of abundant sprouts.

Rates of litter decomposition were estimated from contents of litterbags placed on the forest floor in both unburned and heavi burned black spruce stands. The nylon mesh bags contained three types of litter: black spruce needles and blueberry and Labrado tea leaves. Preliminary results indicated that rates of decompos tion were the same in burned and unburned stands. Black spruce needles and Labrador-tea leaves had about 31-percent weight loss after 2 years; blueberry leaves lost 37 percent of their weight.

Black spruce is a species ideally suited to reseed an area disturbed by fire. Since its cones are semiserotinus, the fire-killed tree can continue to release considerable quantities of seed for years. To compare quantity and quality of seed from burned sites with that of seed from unburned sites, we followed seed dispersal and seedling establishment in lightly and heavily burned stands and an unburned control. During the 1st year afte the fire, black spruce seed fall in the burned plots (average of 331/m^2) was almost four times as great as that in the unburned control (85/m^2). Despite more seed from burned trees, timing of seed dispersal was the same in burned and unburned stands. Peak dispersal occurred in midsummer during periods of high temperatur and low humidity. Seed quality was apparently adversely affecte by high temperatures. Testing of seed dispersed the 1st year aft the fire showed higher percentages of germination in the unburne control and lightly burned stands than in the heavily burned are

Also, the germination capacity of seed from fire-killed trees appeared to decrease with time. Germination for filled seeds averaged 90, 65, and 32 percent for seeds collected from burned black spruce trees 1, 2, and 3 years after the fire, respectively. Even if only germinable seed are considered, seedling establishment appears to be difficult on burned sites. Counts indicated that on burned plots only 1 percent of germinable seeds actually developed into established seedlings.

To more closely follow trends in germination and establishment of tree seedlings in recently burned areas, we carried out an artificial seeding experiment the summer of 1972. Black spruce, white spruce, and paper birch seeds were sown in early June on plots having a north and south aspect. Birch germination reached a peak in mid-June to late June on both north- and south-facing slopes. Germination of both white and black spruce seed peaked in late June on the north slope, but the germination period was more diffuse and spread out on the south slope. Seedling mortality occurred earlier on the south slope plots and appeared to be mainly caused by high temperatures and desiccation. Factors causing seedling mortality on the north slope were browsing, damping-off, and smothering by competing vegetation. By September, however, the proportion of surviving seedlings was approximately the same on both aspects. Percentage of seedling survival was highest for black spruce, second for white spruce, and lowest for paper birch.

Studies of animals after the fire focused on insects, microtine rodents, and snowshoe hares. Numbers of spiders, Collembola, mites, Coleoptera, and other arthropods were followed in burned and unburned areas during the summers of 1972 and 1973. During both years, the burned area supplied more captured specimens than the unburned. It does not, however, necessarily follow that insect numbers were higher in the burned area; it might simply indicate a higher degree of arthropod activity. The numbers captured in all categories except spiders decreased appreciably in 1973. This decline in numbers in most arthropod populations was attributed to predation by spiders.

Voles were live trapped in a heavily burned area and an adjacent unburned control for the first 3 years after the fire. Despite the presence of numerous northern red-backed voles in the unburned area, its activity in the burned area was very low and strictly confined to the period from late July to early November in 1972 and 1973. Starting in July 1974, the population of red-backed voles in the burned area increased substantially and some overwintered there for the first time in 1974-75. The tundra vole was apparently very rare in the unburned black spruce stands where only one animal was ever caught. Tundra voles, however, entered the burned area in early spring of 1974, and the population increased until mid-August when a moderate decline set in. By the 3d year after the fire, both red-backed voles and tundra voles had apparently established resident populations in the burned area.

The fire coincided with the high point in the 10-year population cycle of the snowshoe hare. Consequently, in the fall of 1971, the hares consumed large quantities of willow sprouts that were already coming up in the burned area. During the winter, when the supply of sprouts was exhausted, the hares fed on charred bark. The population continued at high levels until 1973 and consumed all the available hardwood browse in the unburned control and for at least 200 m into the burned area. In 1974, density of hares decreased and intensity of browsing fell off. Trapping data indicated that the population of snowshoe hares varied from a high of six hares per hectare in the fall of 1971 to a low of 0.12 hare/ha in the spring of 1975. Despite the fact that some hares were trapped in the burned area, there appeared to be no permanent residents there even 3 years after the fire.

Results of trapping and analysis of stomach contents revealed that hares migrate seasonally and substantially change their diet. In summer, they prefer open areas where blueberry, lowbush cranberry, and herbaceous plants are most plentiful. In the winter, hares move back into dense black spruce stands where they feed on spruce, willow, and alder. Even heavy browsing on hardwoods appears to be beneficial; it stimulates lateral branching and, hence, greater productivity.

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